Mathematica with ROOT

Sebastian White, Feb. 22, 2011
Feynman Computing Center, Fermilab

talk outline

- The single electron project
- ATLAS ZDC signal reconstruction
- Mathematica_ROOT= the "deliverable"

papers from 2010

- "Neutron Production and Zero Degree Calorimeter Acceptance at LHC", Sebastian White, http://adsabs.harvard.edu/abs/2009arXiv0912.4320W

"Beam Fragmentation in Heavy Ion Collisions and its implication for RHIC triggers at low s", Sebastian White, Mark Strikman, http://arxiv.org/abs/0910.3205

"The role of Spectator Fragments at an electron Ion collider", Sebastian White and Mark Strikman, http://arxiv.org/pdf/1003.2196

"Diffraction at the LHC: a non-technical Introduction" , Sebastian White, http://arxiv.org/abs/1003.4252

"Energy Calibration of Underground Neutrino Detectors using a 100 MeV electron accelerator", Sebastian White, Vitaly Yakimenko, http://arxiv.org/abs/1004.3068

Earlier paper on requirements for FP420 timing:

On the Correlation of Subevents in the ATLAS and CMS/Totem Experiments

Sebastian N. White arXiv:0707.1500v3

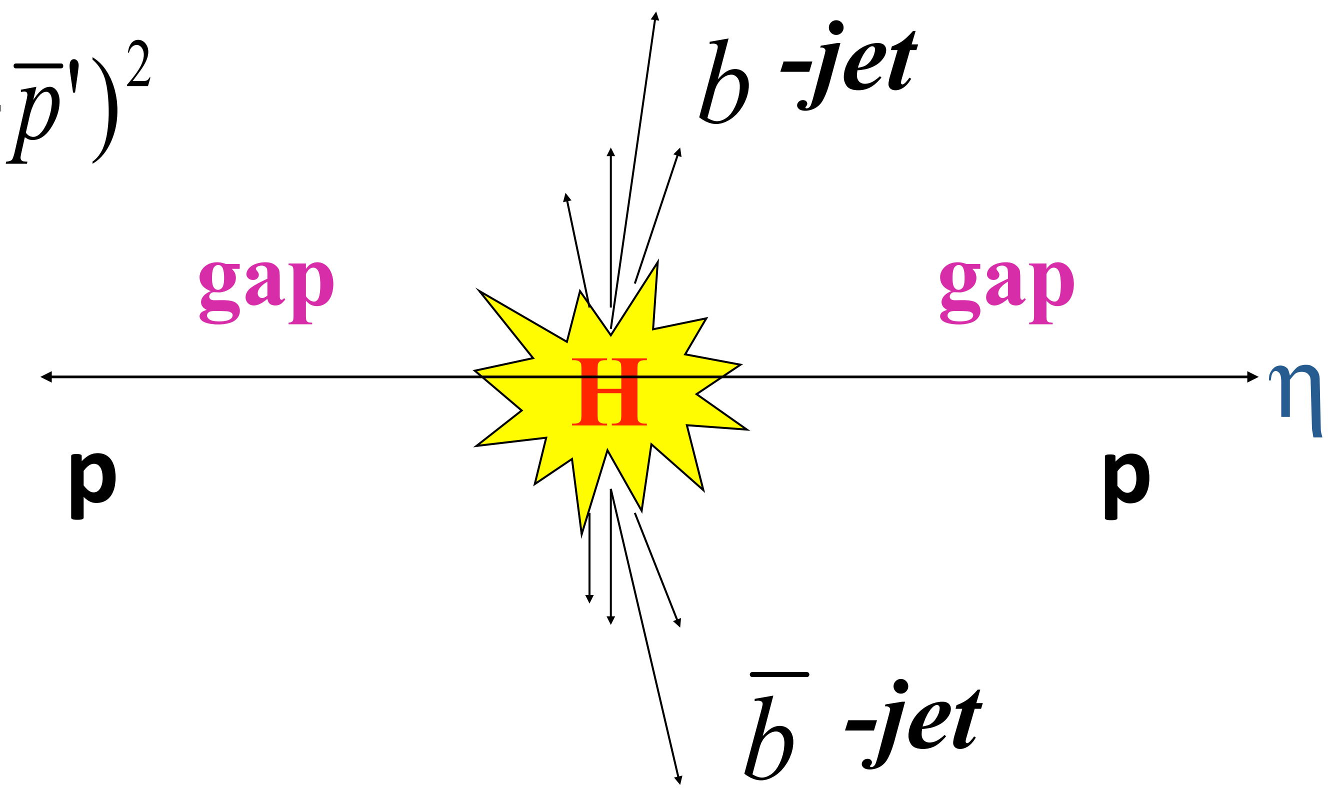
Central Exclusive Higgs Production

the issues regarding fast timing are well known here at FNAL. There is not yet any existing technology which can survive 10^34 at LHC

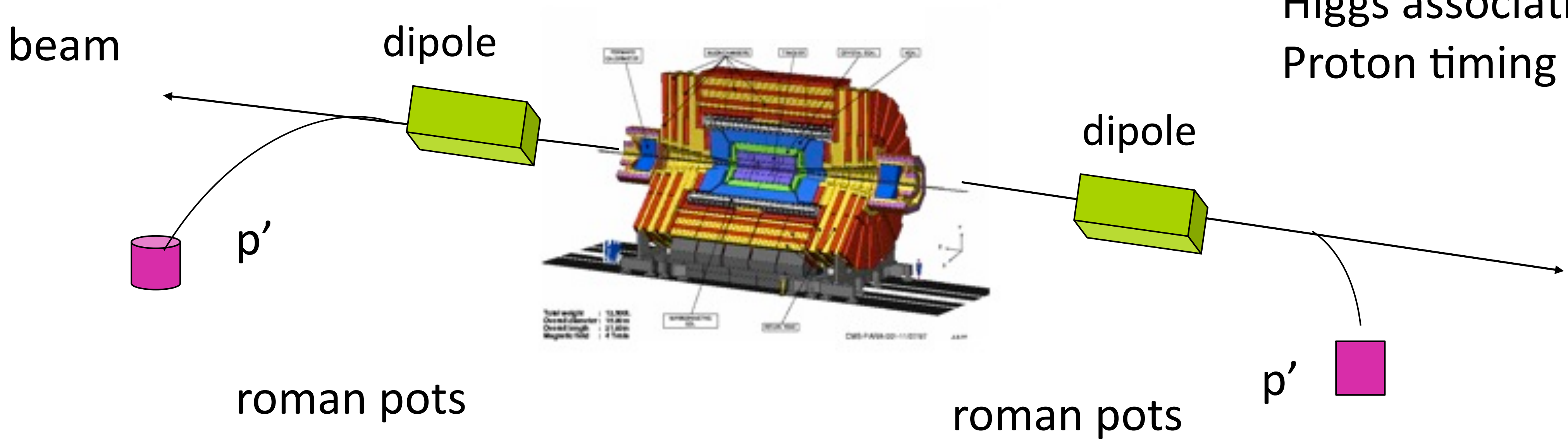
$$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$$

$\Delta M = O(1.0 - 2.0)$ GeV

Background suppressed
By 0^+ selection rule



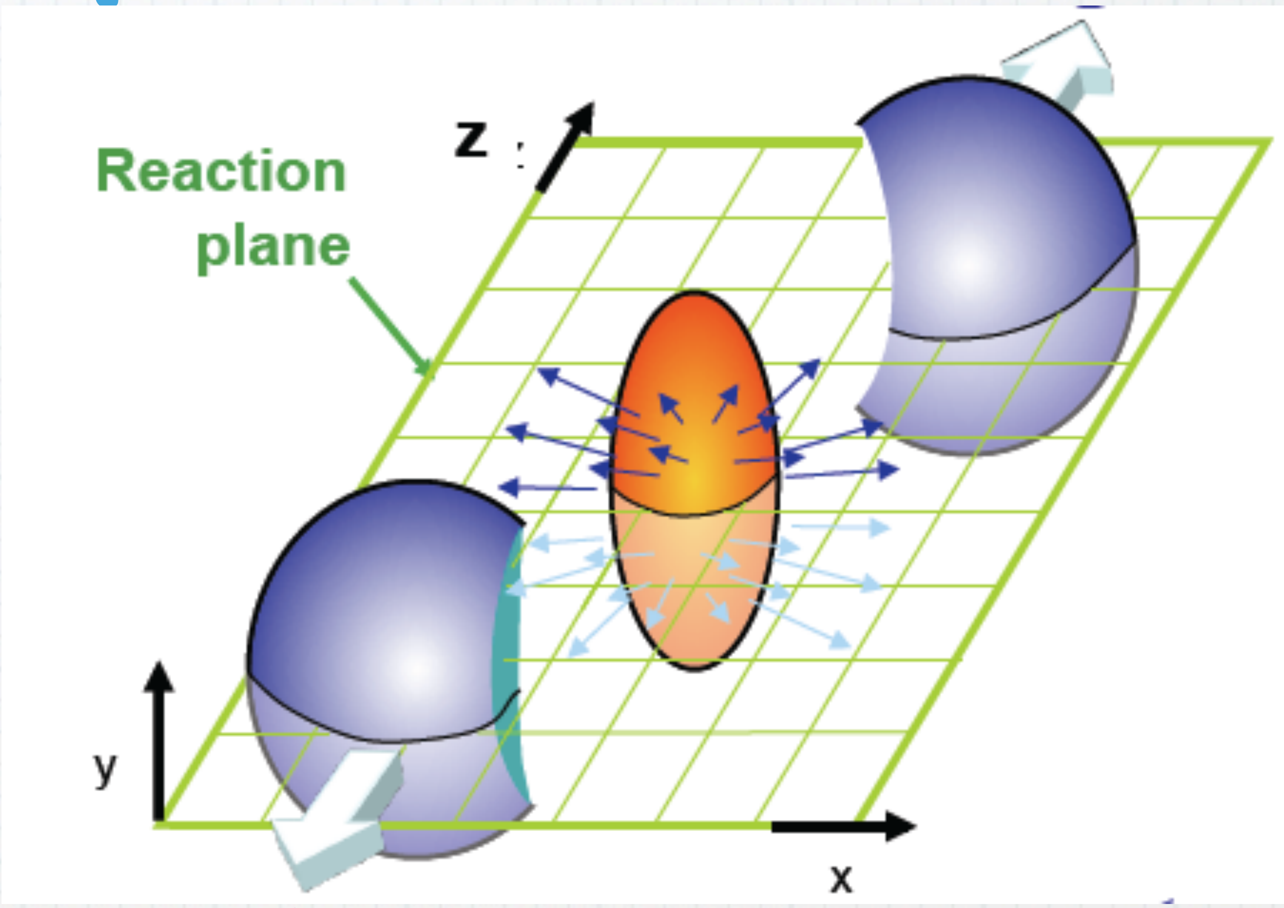
Higgs association from
Proton timing (~ 10 picosecond)



what do we know about forward neutron production? 1) Heavy Ions

Standard Picture ->

(Masashi Kaneta/Shinichi Esumi)

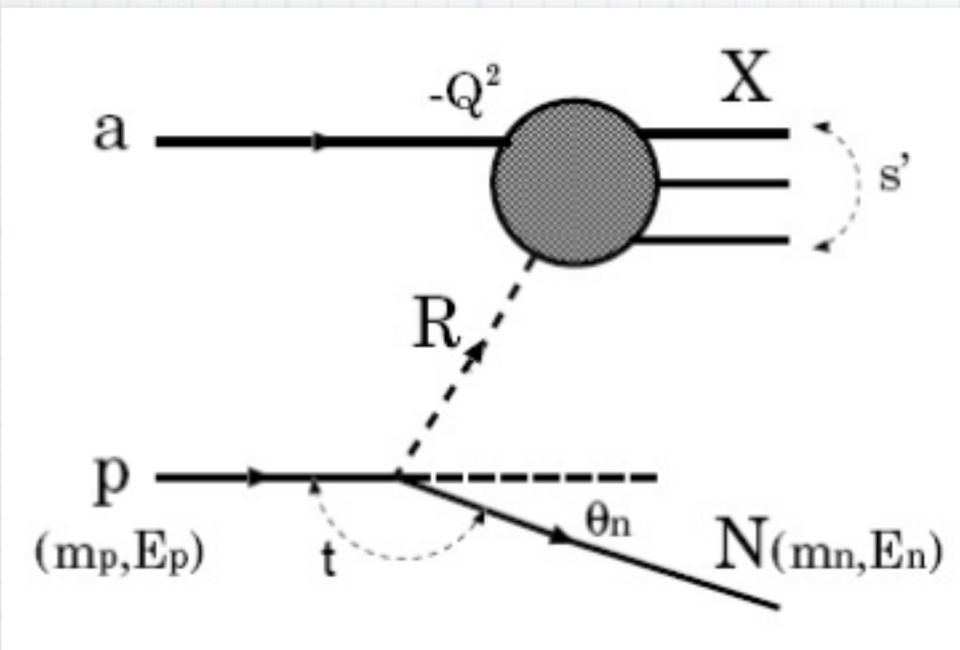


forward neutrons measure:
-impact parameter
-reaction plane (from directed flow, v_1)

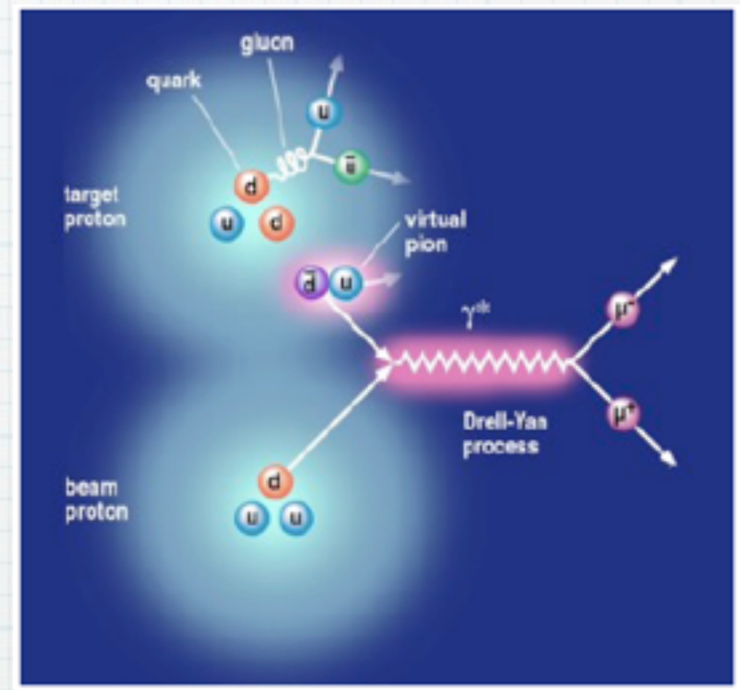
Surprisingly, significant aspects of this picture not modeled in HIJING !
- ie in HIJING, Fermi motion=0 !
-> new collaboration to include modeling of baryon "spectators"- Alvioli, Csorgo, Strikman, Vargyas, SNW

Neutron Production in pp

* most people have the following picture



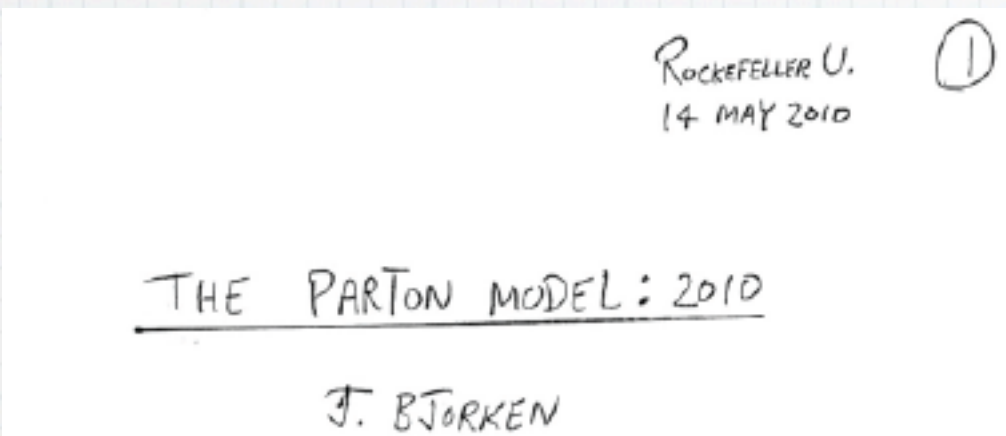
ie->

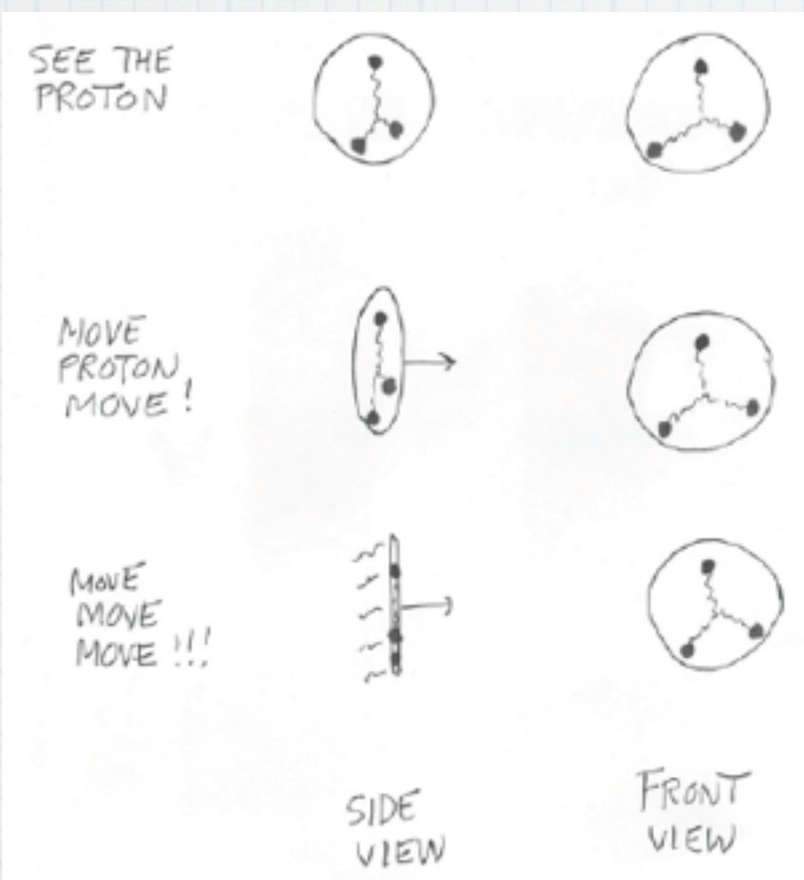


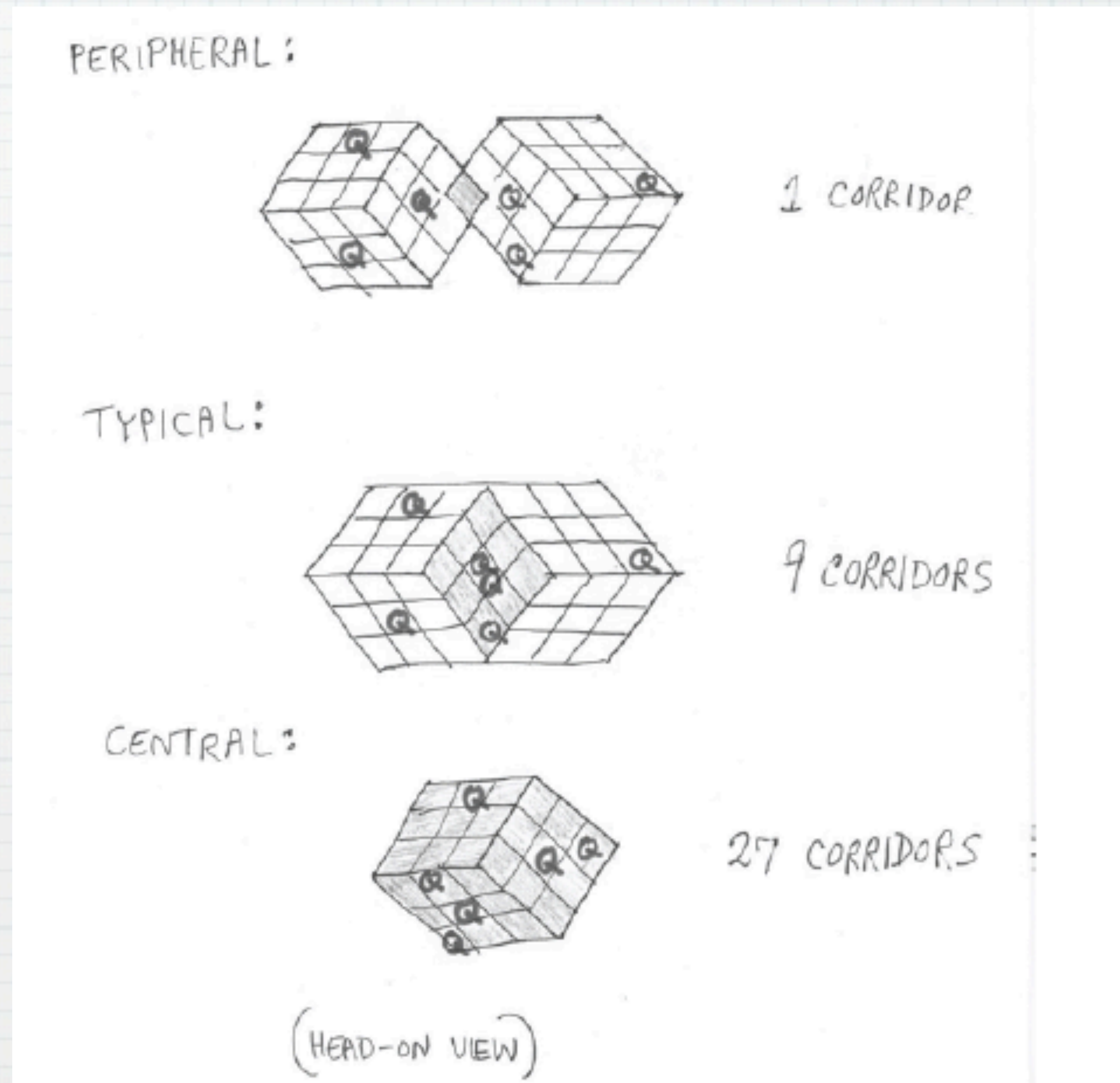
in RAPGAP "replace the Pomeron by pi+"

inadequate (see Sunday's talk)

Bjorken's picture

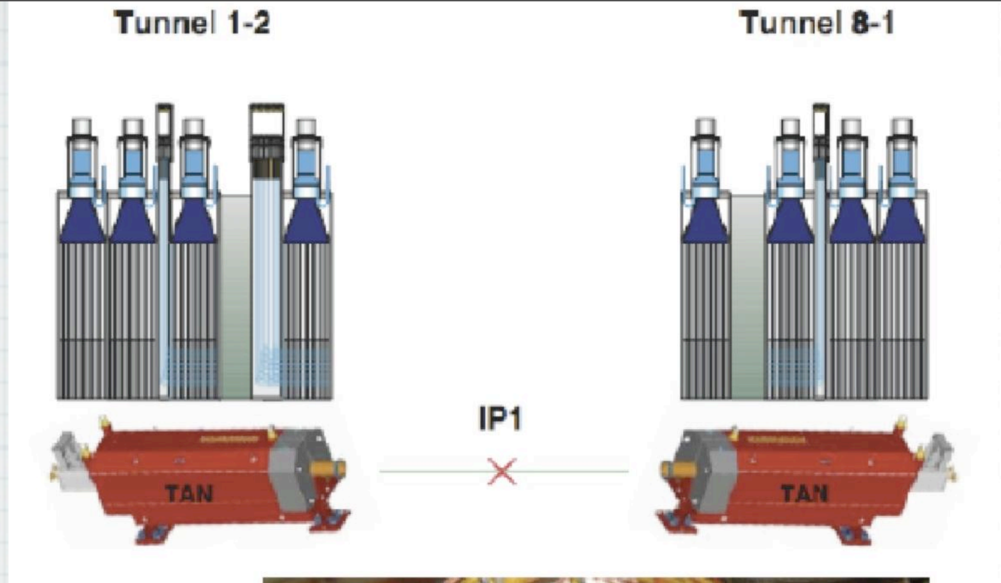






* Phenomonology of Inclusive neutron production from ISR, FNAL, HERA, RHIC
* coincident 2 neutron only from PHENIX
* ->modeling of LHC cross sections "Neutron Production and Zero Degree Calorimeter Acceptance at LHC"-SNW- arXiv:0912.4320v2 [hep-ph] In this model of non-diffractive +diffractive:
    * always a forward baryon, w. x_F & p_t given by HERA
    * 45% of these baryons are neutrons
    * to calculate 2 arm coincidence assume left-right distributions are uncorrelated. early comparison with this model by ATLAS (blessed in June):

Trigger type	ZDC-A_and_ZDC-C	ZDC-A_inclusive
σ(Effective) mbarn	4.4 +/- 0.6	17.6 +/- 1.3



ATLAS ZDC had severe constraints compared to PHENIX
-5 Giga Rad/yr rad dose @ design lum
=200 Watt continuous beam deposition
LHC politics vis. LHCf, LUMI...

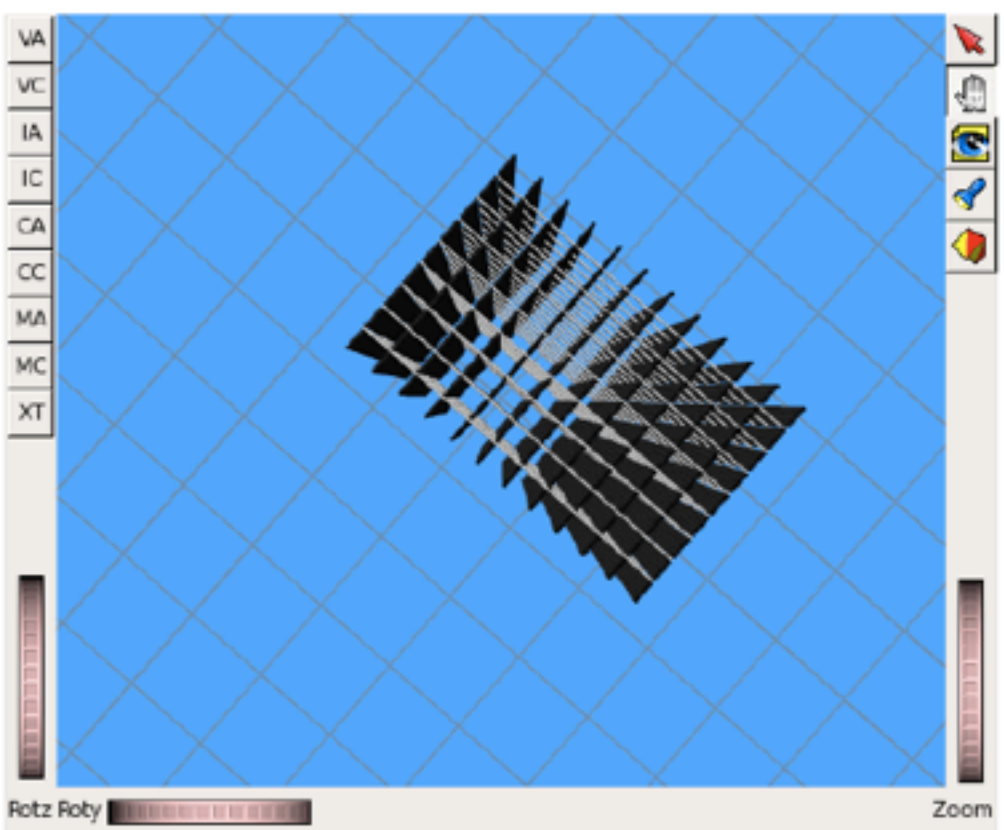
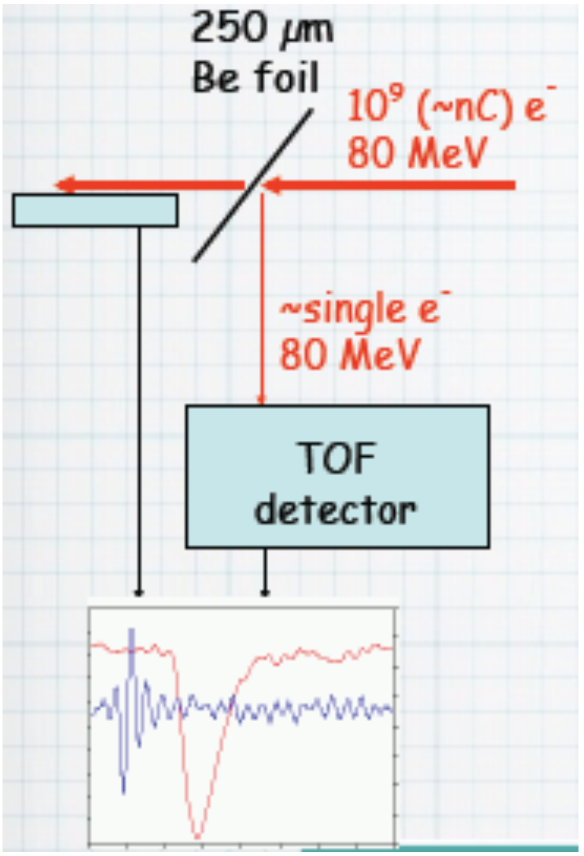
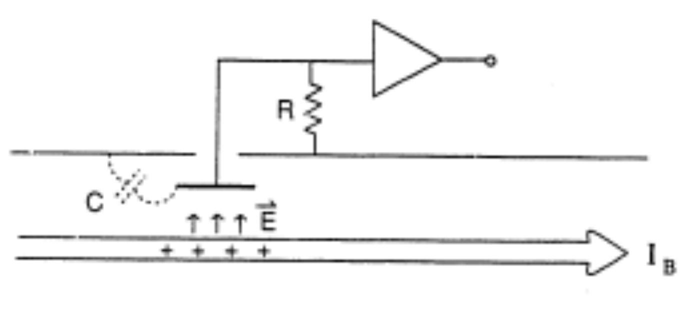


Figure 4: ZDC Drawn with VP1. Plot shows the grid of Strips and Pixels within the EMXY Module

despite constraints
-> ATLAS is the only imaging ZDC (x,y,z) on the planet
"shashlik"/layer sampling hybrid

The single electron project



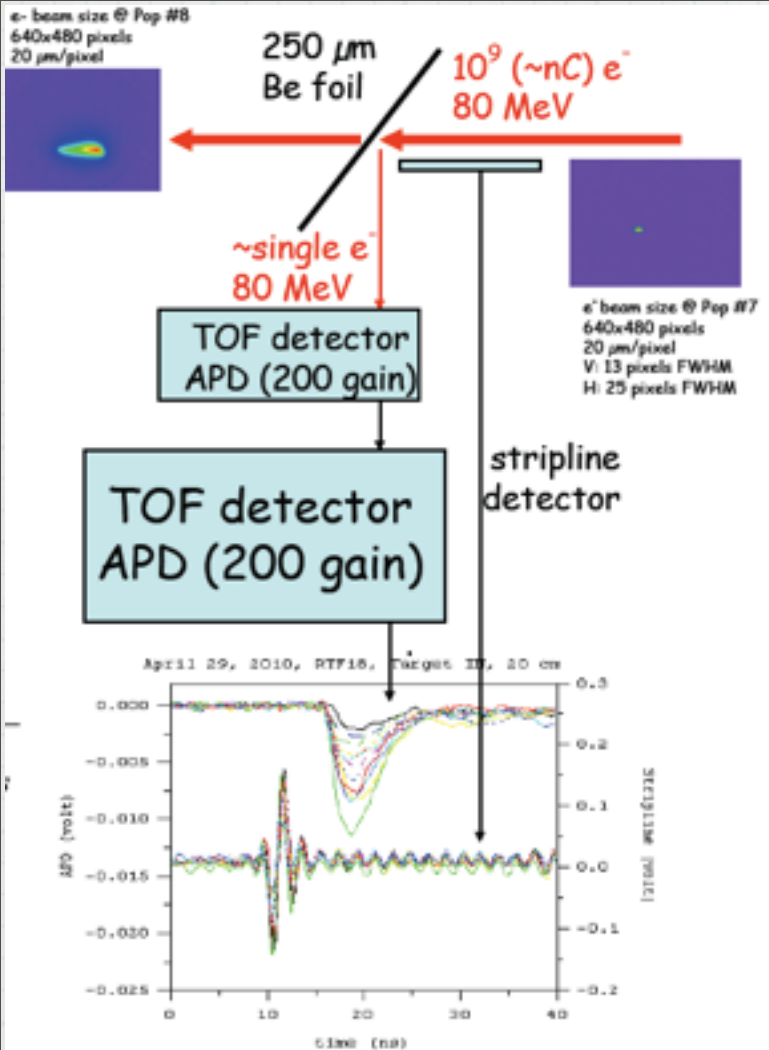


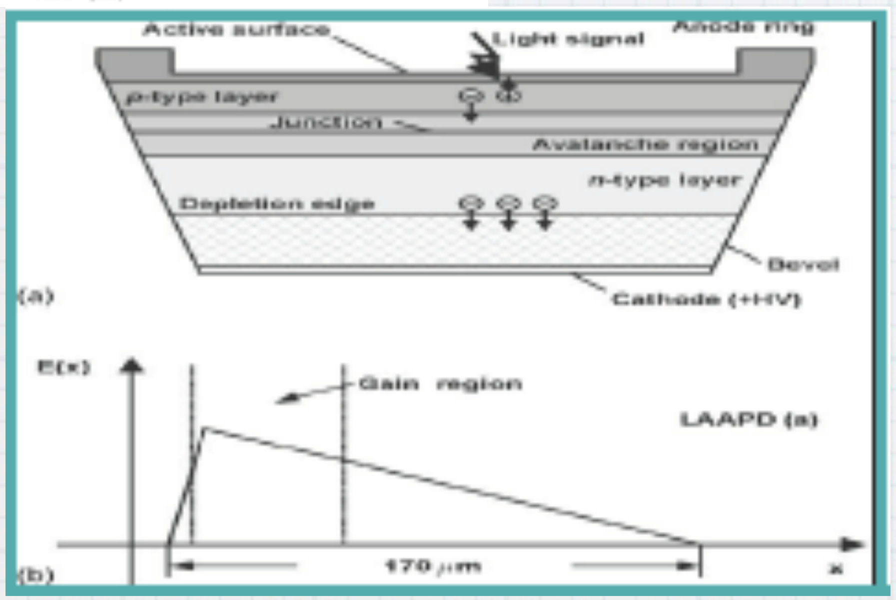
- a unique feature of ATF beam is 3 picosec bunch length(streak camera)
- could this be exploited to evaluate fast timing detectors?
- common technique for secondary beam design is successive dispersion and collimation
- this requires real estate

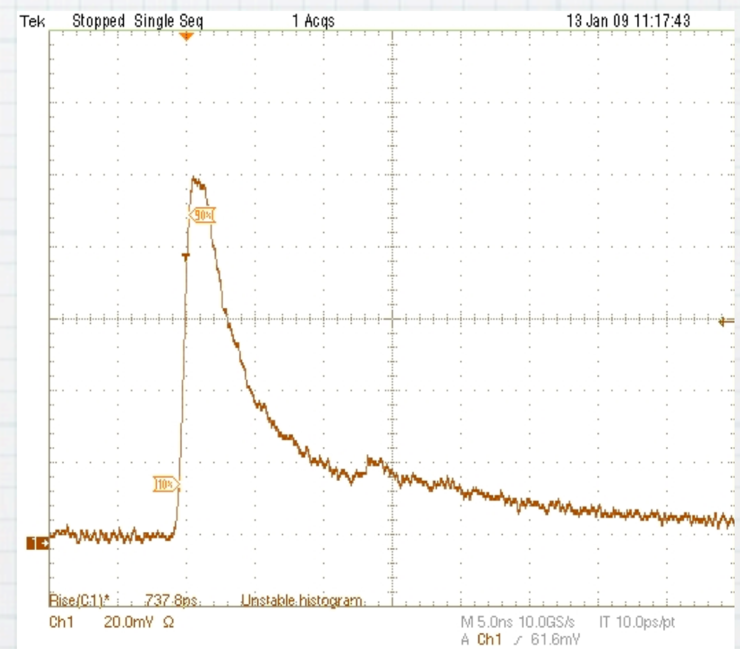
representing work of:
V. Yakimenko,
M.Fedurin, T. Tsang, M.Chiu, M.Diwan, G.Atoian(BNL)
K.McDonald(Princeton- my co-PI on ADR&D)

correspondents:
H.Frisch, J.Va'vra, K.Goulianos, D.Acker, I.Mousienko,
M.Suyama, C. Royon, C. Williams

Why is a 100 MeV, single electron, 3 picosecond beam interesting?







Deep diffused avalanche photodiode

650 picosecond risetime (β's)

"A 10 picosecond time of flight detector using APD's", SNW et al.

- **Question: with an incident beam of 10^9 60-80 MeV electrons, a ~1 mm target (Al or Be), how many are scattered @90 degrees into a ~1cm^2 detector 30 cm away?**

  Answer: ~1 !

- calculations presented in:"LBNE energy calibration using a 100 MeV electron accelerator"-SNW& Vitaly Yakimenko http://arxiv.org/abs/1004.3068
- small accelerators previously used for calibration. ie:
- **Super K made good use of a 5-16 MeV medical accelerator -Mitsubishi ML-15MIII. They used a conventional secondary beam design (requires space)**

Wide angle electron scattering

Approximations to Hofstadter' s form:

$$\text{Rutherford}[\theta\_,\ Z\_,\ \text{EeMeV}\_] := 1/4\ (Z * \alpha_{EM})^2\ \frac{\hbar c1^2}{\text{EeMeV}^2}\ \text{Csc}[\theta/2]^4$$

$$\text{Mott}[\theta\_,\ Z\_,\ \text{EeMeV}\_] := \text{Rutherford}[\theta,\ Z,\ \text{EeMeV}] * \text{Cos}[\theta/2]^2 \left(1 + \frac{\pi * Z * \alpha_{EM} * \text{Sin}[\theta/2] * (1 - \text{Sin}[\theta/2])}{\text{Cos}[\theta/2]^2}\right)$$

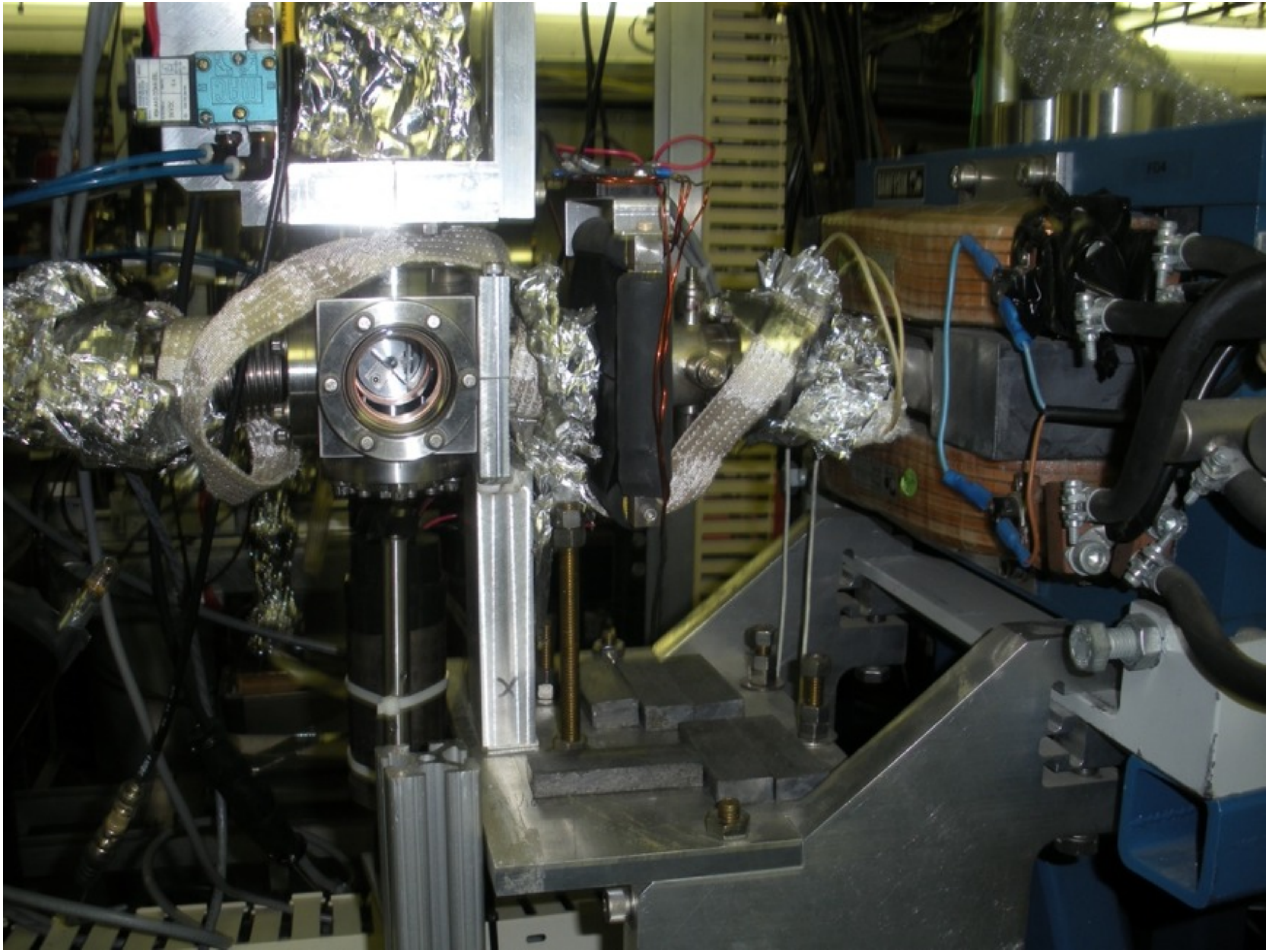
$$Q[\theta\_,\ \text{EeMeV}\_] := \frac{2 * \text{EeMeV}}{\hbar c}\ \text{Sin}[\theta/2]$$

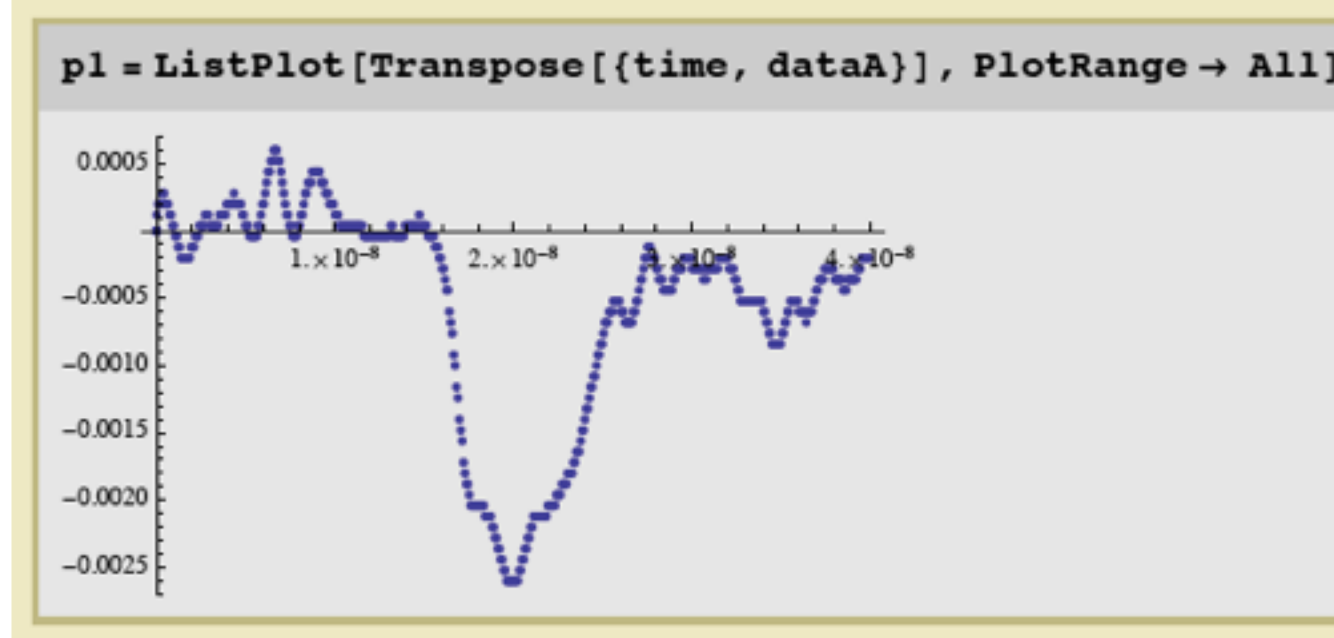
$$\rho[r\_,\ a\_] := \frac{1}{8\pi\ (a)^3}\ \text{Exp}[-r/a]$$

$$\text{FormFactor}(\theta\_,\ a\_,\ \text{EeMeV}\_) := \frac{4\pi \int_0^\infty r\, \rho(r, a) \sin(r\, Q(\theta, \text{EeMeV}))\, dr}{Q(\theta, \text{EeMeV})}$$

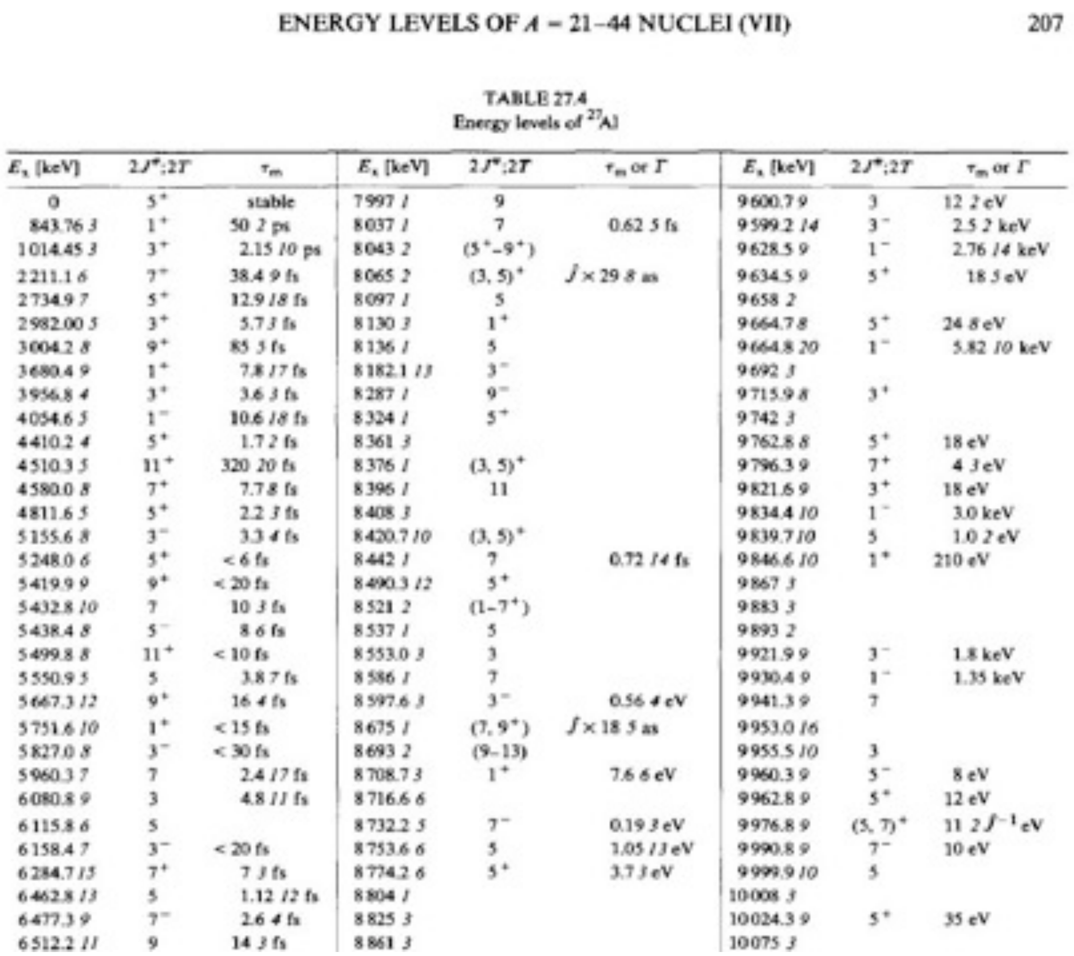
$$\text{Hofstadter}[\theta\_,\ Z\_,\ \text{EeMeV}\_,\ a\_] := \text{Mott}[\theta, Z, \text{EeMeV}] * \text{FormFactor}[\theta, a, \text{EeMeV}]^2$$

the beamline





Al is very messy!



ENERGY LEVELS OF A = 21–44 NUCLEI (VII) 207

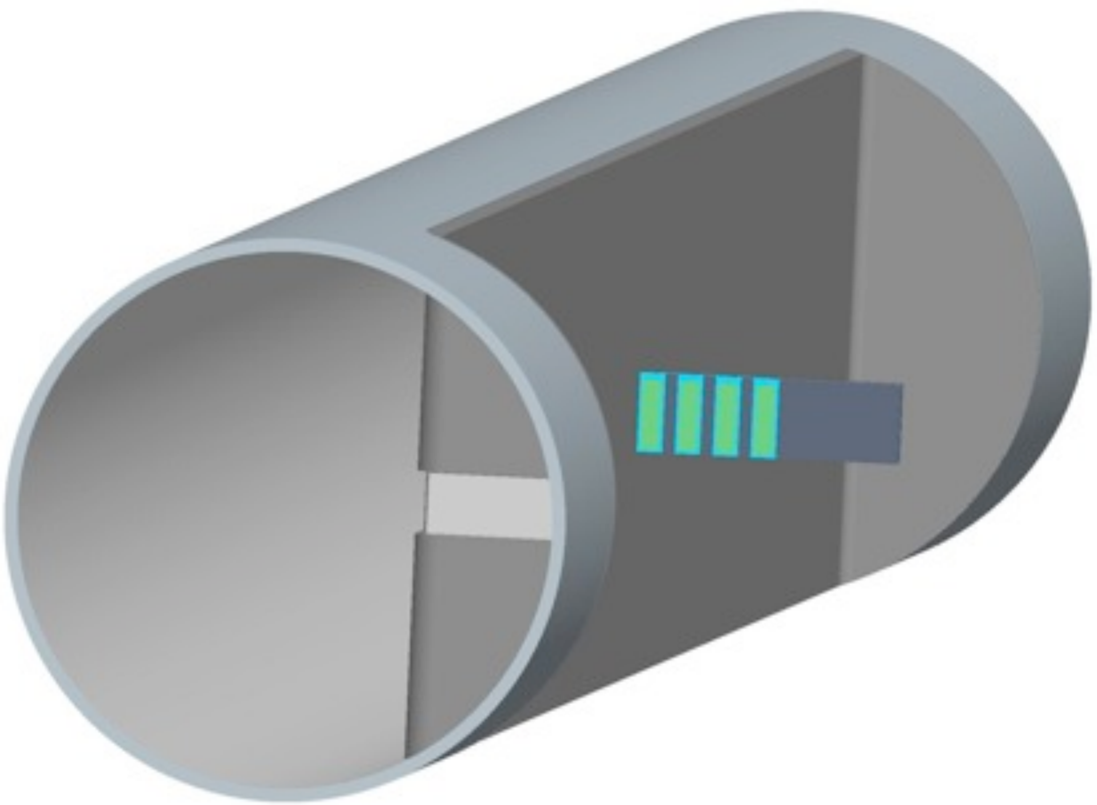
TABLE 27.4
Energy levels of ^{27}Al

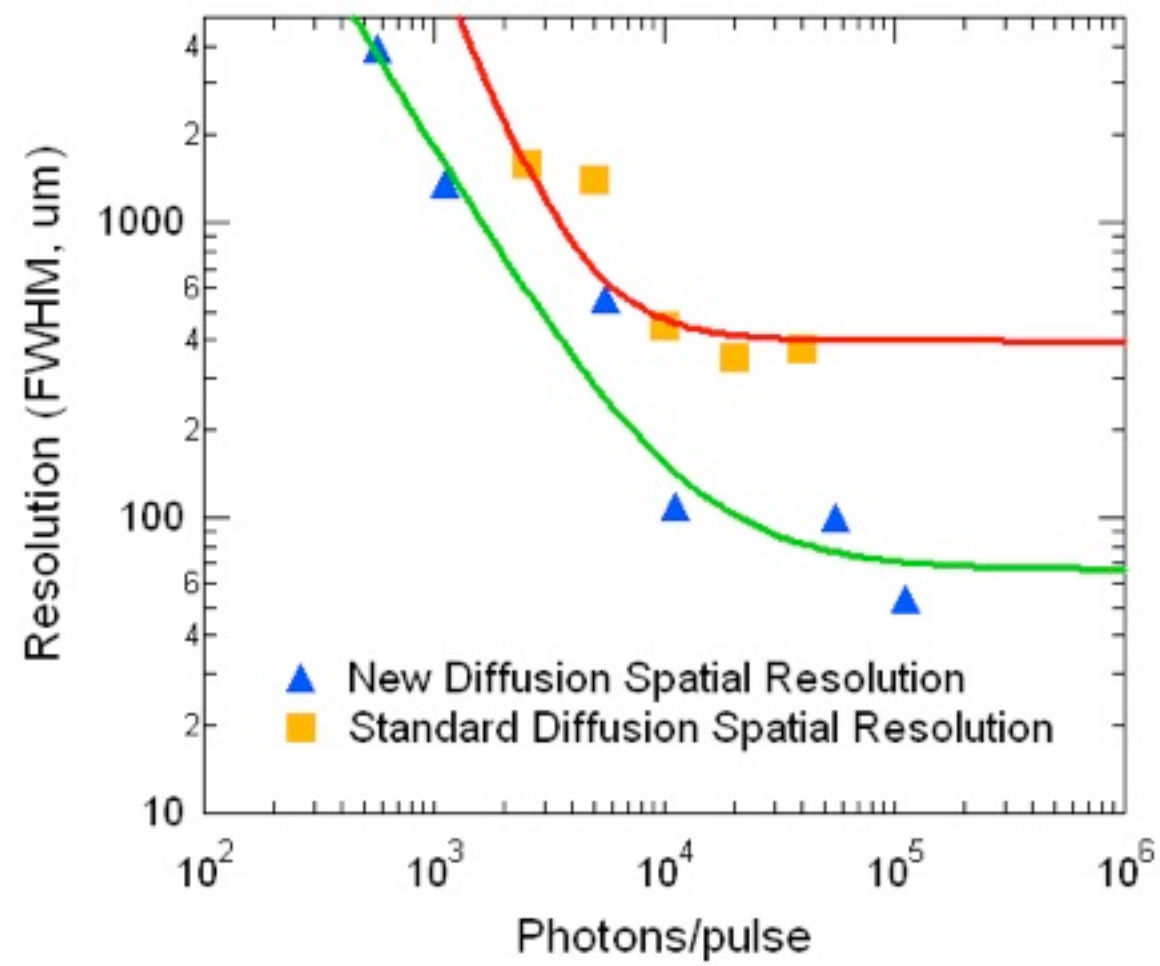
E_x [keV]	$2J^\pi;2T$	τ_m	E_x [keV]	$2J^\pi;2T$	τ_m or Γ	E_x [keV]	$2J^\pi;2T$	τ_m or Γ
0	5^+	stable	7997 *1*	9		9600.7 9	3	12 *2* eV
843.76 *3*	1^+	50 *2* ps	8037 *1*	7	0.62 *5* fs	9599.2 *14*	3^-	2.5 *2* keV
1014.45 *3*	3^+	2.15 *10* ps	8043 *2*	$(5^+–9^+)$		9628.5 9	1^-	2.76 *14* keV
2211.1 *6*	7^+	38.4 *9* fs	8065 *2*	$(3, 5)^+$	$J \times 29$ *8* as	9634.5 9	5^+	18 *5* eV
2734.9 7	5^+	12.9 *18* fs	8097 *1*	5		9658 *2*		
2982.00 *5*	3^+	5.7 *3* fs	8130 *3*	1^+		9664.7 *8*	5^+	24 *8* eV
3004.2 *8*	9^+	85 *5* fs	8136 *1*	5		9664.8 *20*	1^-	5.82 *10* keV
3680.4 9	1^+	7.8 *17* fs	8182.1 *13*	3^-		9692 *3*		
3956.8 *4*	3^+	3.6 *3* fs	8287 *1*	9^-		9715.9 *8*	3^+	
4054.6 *5*	1^-	10.6 *18* fs	8324 *1*	5^+		9742 *3*		
4410.2 *4*	5^+	1.7 *2* fs	8361 *3*			9762.8 *8*	5^+	18 eV
4510.3 *5*	11^+	320 *20* fs	8376 *1*	$(3, 5)^+$		9796.3 9	7^+	4 *3* eV
4580.0 *8*	7^+	7.7 *8* fs	8396 *1*	11		9821.6 9	3^+	18 eV
4811.6 *5*	5^+	2.2 *3* fs	8408 *3*			9834.4 *10*	1^-	3.0 keV
5155.6 *8*	3^-	3.3 *4* fs	8420.7 *10*	$(3, 5)^+$		9839.7 *10*	5	1.0 *2* eV
5248.0 *6*	5^+	< 6 fs	8442 *1*	7	0.72 *14* fs	9846.6 *10*	1^+	210 eV
5419.9 9	9^+	< 20 fs	8490.3 *12*	5^+		9867 *3*		
5432.8 *10*	7	10 *3* fs	8521 *2*	$(1–7^+)$		9883 *3*		
5438.4 *8*	5^-	8 *6* fs	8537 *1*	5		9893 *2*		
5499.8 *8*	11^+	< 10 fs	8553.0 *3*	3		9921.9 9	3^-	1.8 keV
5550.9 *5*	5	3.8 *7* fs	8586 *1*	7		9930.4 9	1^-	1.35 keV
5667.3 *12*	9^+	16 *4* fs	8597.6 *3*	3^-	0.56 *4* eV	9941.3 9	7	
5751.6 *10*	1^+	< 15 fs	8675 *1*	$(7, 9^+)$	$J \times 18$ *5* as	9953.0 *16*		
5827.0 *8*	3^-	< 30 fs	8693 *2*	(9–13)		9955.5 *10*	3	
5960.3 7	7	2.4 *17* fs	8708.7 *3*	1^+	7.6 *6* eV	9960.3 9	5^-	8 eV
6080.8 9	3	4.8 *11* fs	8716.6 *6*			9962.8 9	5^+	12 eV
6115.8 *6*	5		8732.2 *5*	7^-	0.19 *3* eV	9976.8 9	$(5, 7)^+$	11 *2* J^{-1} eV
6158.4 7	3^-	< 20 fs	8753.6 *6*	5	1.05 *13* eV	9990.8 9	7^-	10 eV
6284.7 *15*	7^+	7 *3* fs	8774.2 *6*	5^+	3.7 *3* eV	9999.9 *10*	5	
6462.8 *13*	5	1.12 *12* fs	8804 *1*			10008 *3*		
6477.3 9	7^-	2.6 *4* fs	8825 *3*			10024.3 9	5^+	35 eV
6512.2 *11*	9	14 *3* fs	8861 *3*			10075 *3*		

Beryllium is excellent!

we now have a backlog of high quality data, with different timing detectors, absorbers and distance to target. Requires ~1 week analysis to make suitable for publication.

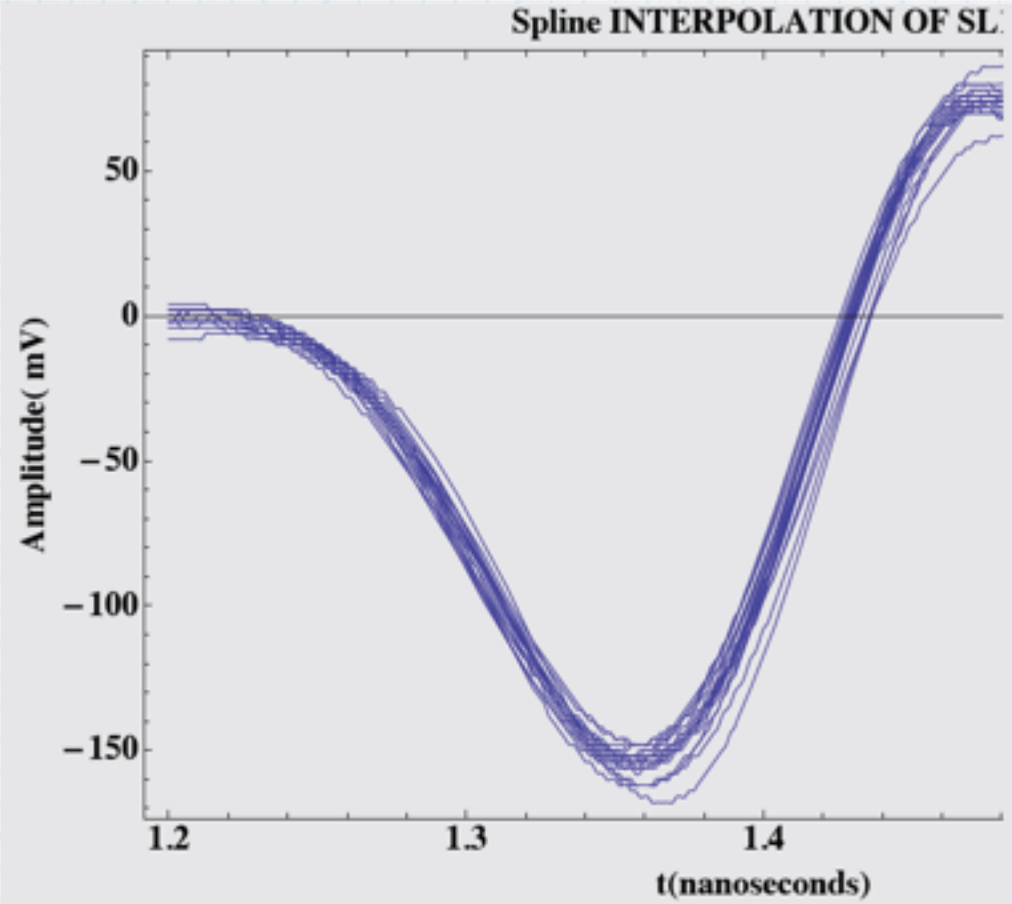
AD R&D proposal to DOE





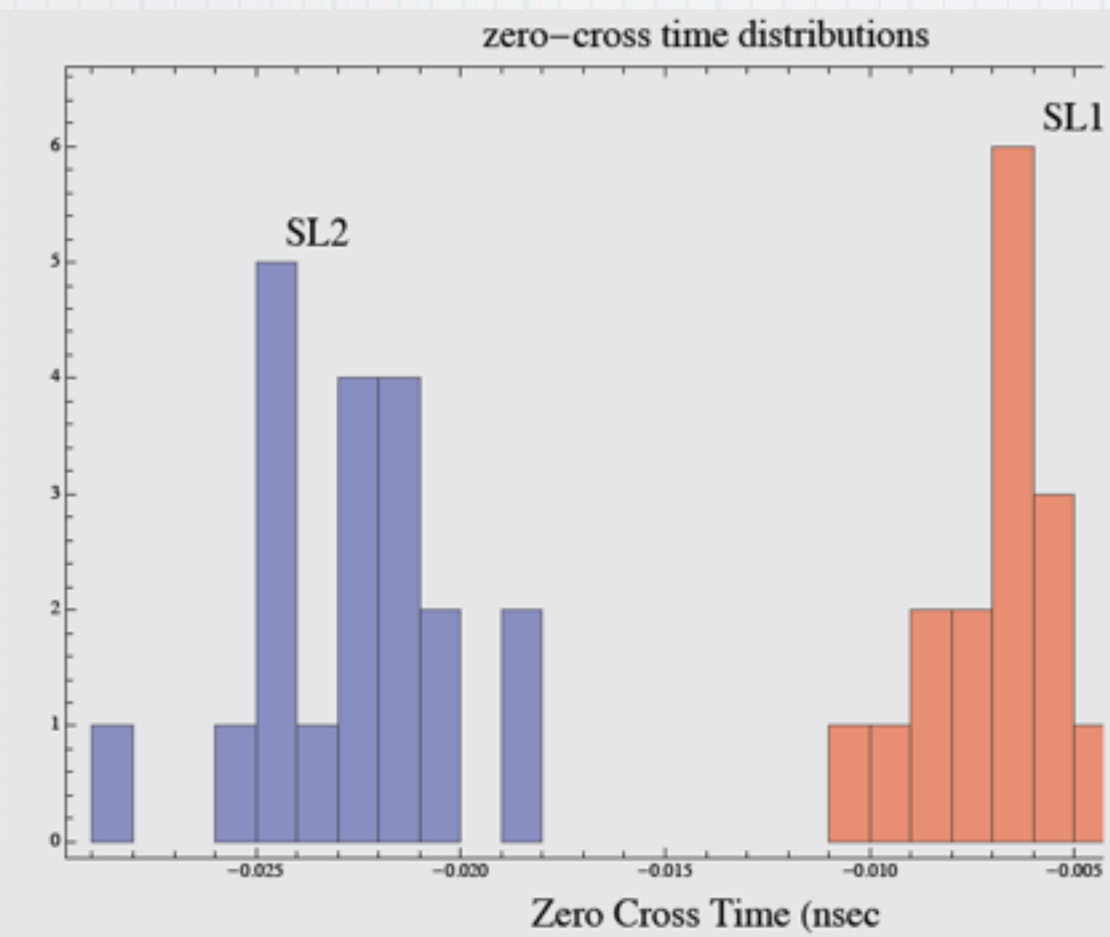
A pretty good silicon tracker with 10 psec time resolution.
currently ~$2M/m^2 sensor cost

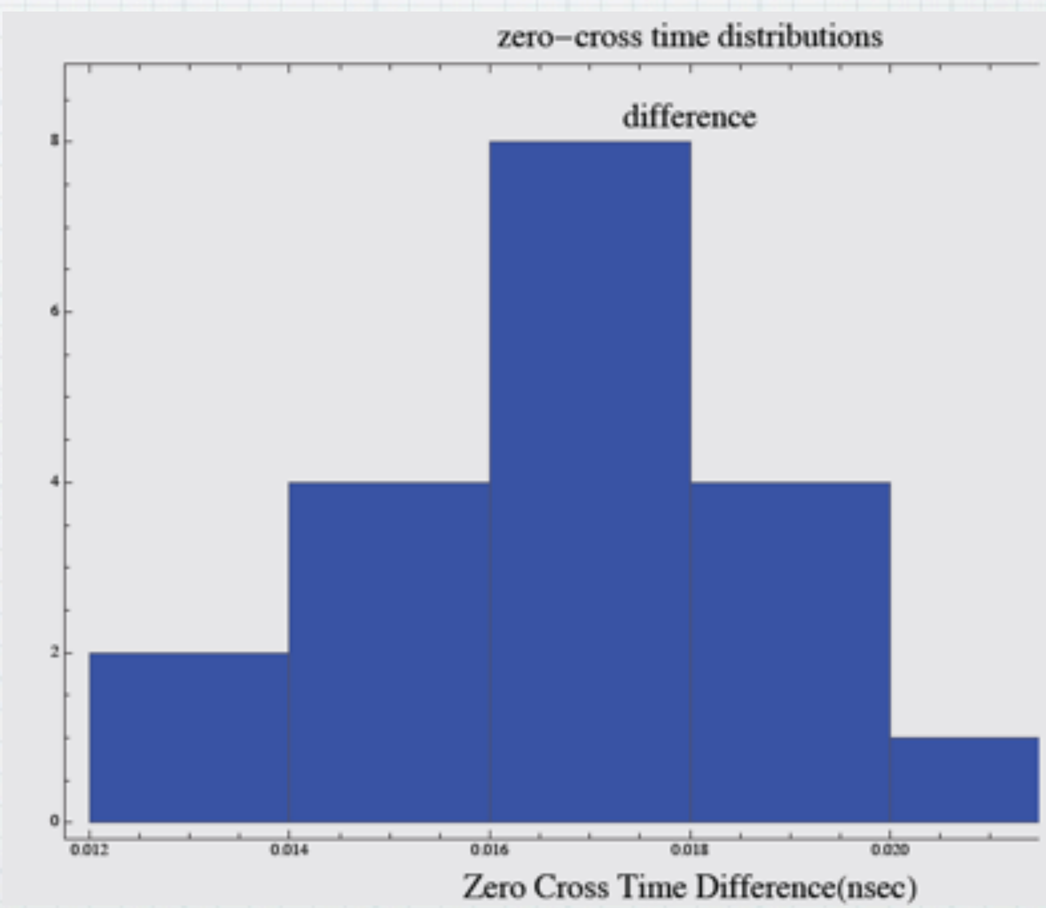
Initial study of “start time” resolution from ATF stripline

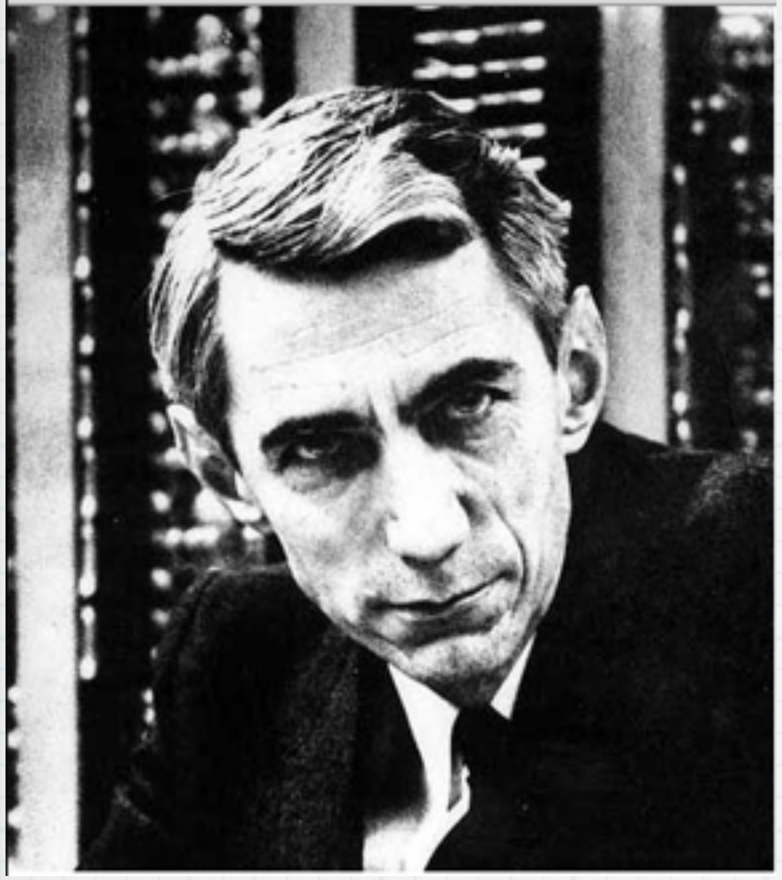


stripline waveforms w.
on-chip Sin[x]/x interpolation+spline

rms on time diff
between detectors <2.5 psec







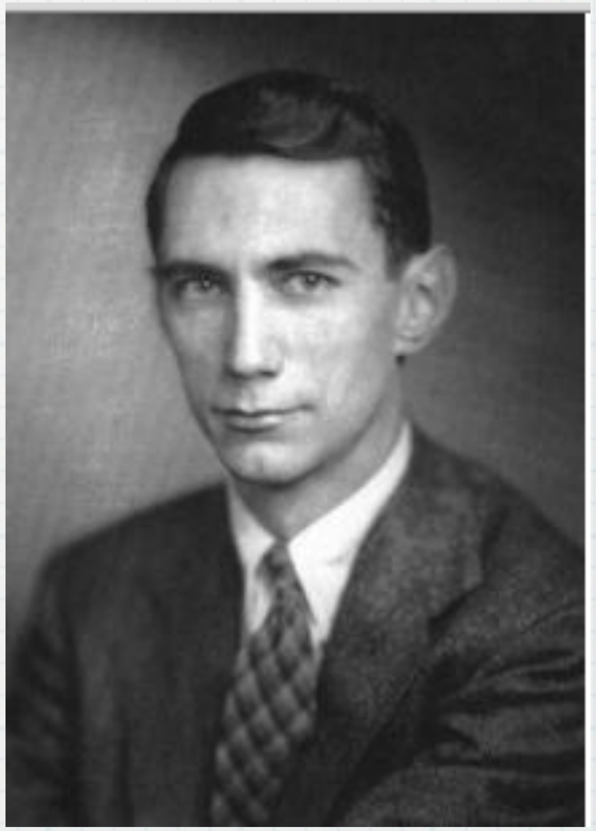
Spinoff: experience at ATF has been very useful. Led to signal reconstruction algorithm for ATLAS ZDC.
Now fastest detector in ATLAS (<100 psec)

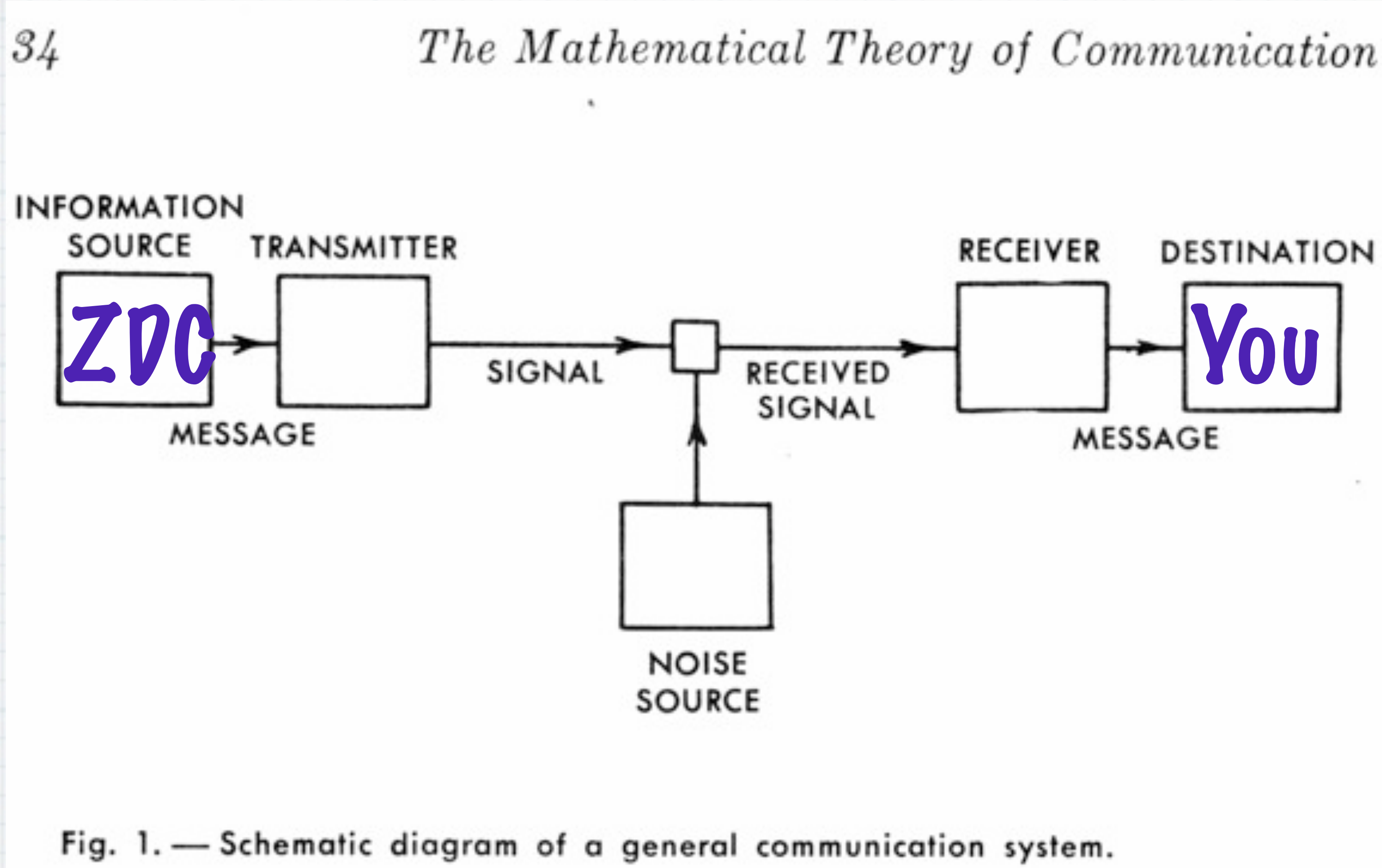
* resulted in Shannon's 1940 PhD thesis at MIT, *An Algebra for Theoretical Genetics*[6]
* Victor Shestakov, at Moscow State University, had proposed a theory of electric switches based on Boolean logic a little bit earlier than Shannon, in 1935, but the first publication of Shestakov's result took place in 1941, after the publication of Shannon's thesis.
* The theorem is commonly called the **Nyquist sampling theorem**, and is also known as **Nyquist–Shannon–Kotelnikov**, **Whittaker–Shannon–Kotelnikov**, **Whittaker–Nyquist–Kotelnikov–Shannon**, **WKS**, etc., sampling theorem, as well as the **Cardinal Theorem of Interpolation Theory**. It is often referred to as simply ***the sampling theorem***.
* The theoretical rigor of Shannon's work completely replaced the *ad hoc* methods that had previously prevailed.
* Shannon and Turing met every day at teatime in the cafeteria.[8] Turing showed Shannon his seminal 1936 paper that defined what is now known as the "Universal Turing machine"[9][10] which impressed him, as many of its ideas were complementary to his own.
* He is also considered the co-inventor of the first wearable computer along with Edward O. Thorp.[16] The device was used to improve the odds when playing roulette.

In 1956 two Bell Labs scientists discovered the scientific formula for getting rich. One was the mathematician Claude Shannon, neurotic father of our digital age, whose genius is ranked with Einstein's. The other was John L. Kelly, Jr., a gun-toting Texas-born physicist. Together they applied the science of information theory—the basis of computers and the Internet—to the problem of making as much money as possible, as fast as possible. Shannon and MIT mathematician Edward O. Thorp took the "Kelly formula" to the roulette and blackjack tables of Las Vegas. It worked. They realized that there was even more money to be made in the stock market, specifically in the risky trading known as arbitrage. Thorp used the Kelly system with his phenomenally successful hedge fund Princeton-Newport Partners. Shannon became a successful investor, too, topping even Warren Buffett's rate of return and

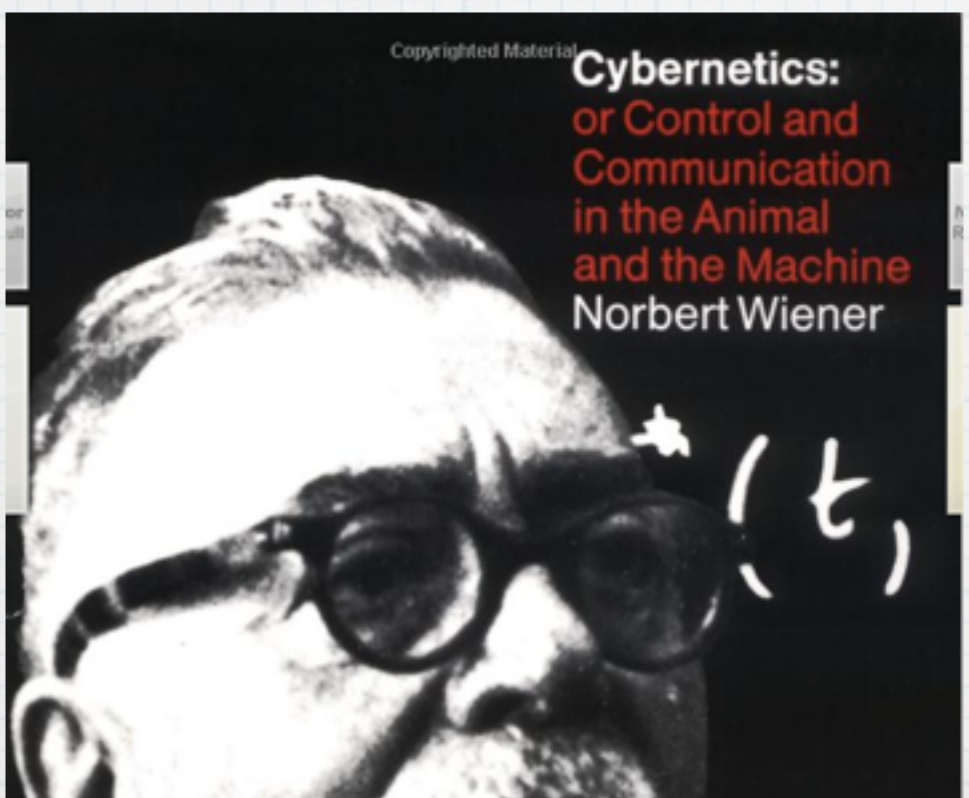
no time to discuss Shannon's method for getting rich

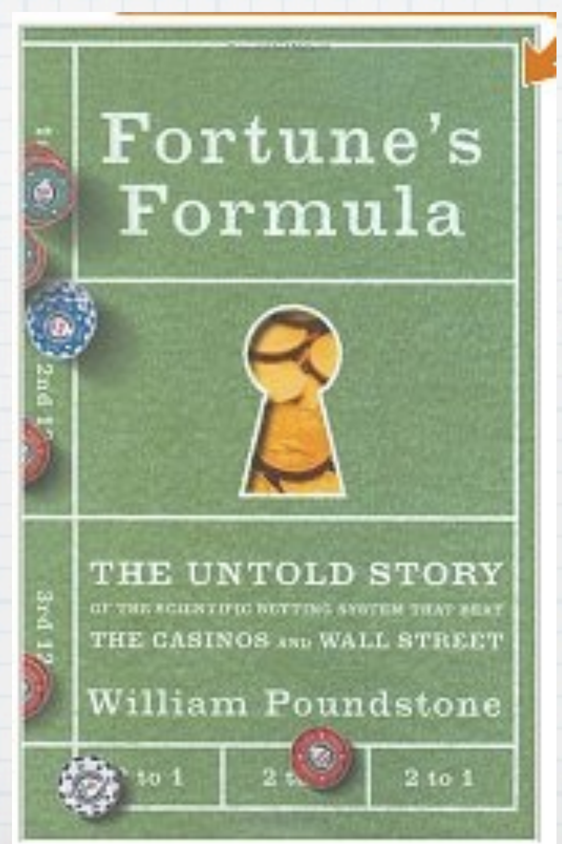
will discuss Shannon's method for reconstructing digitized waveforms



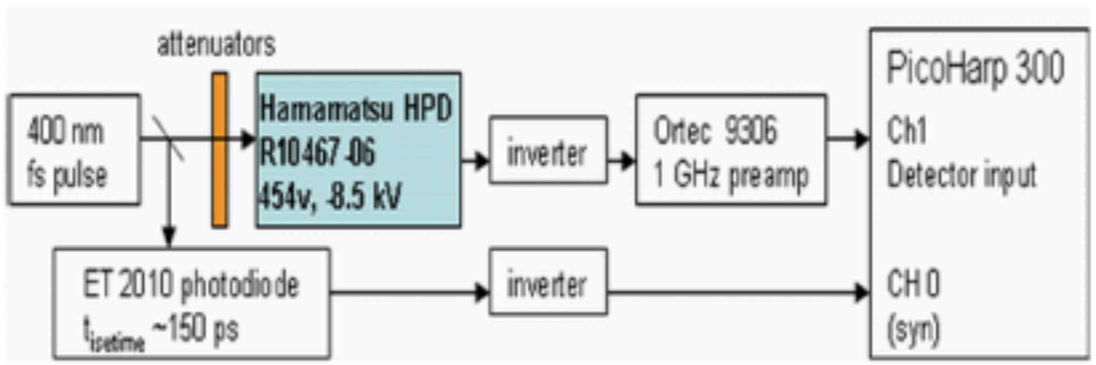


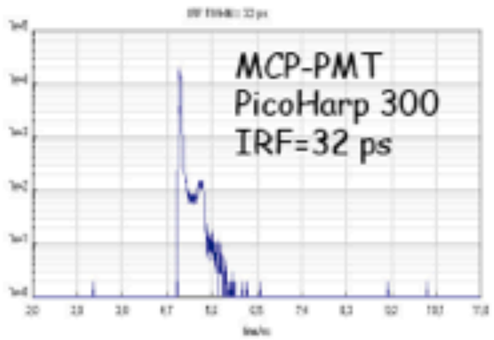
books about Shannon:

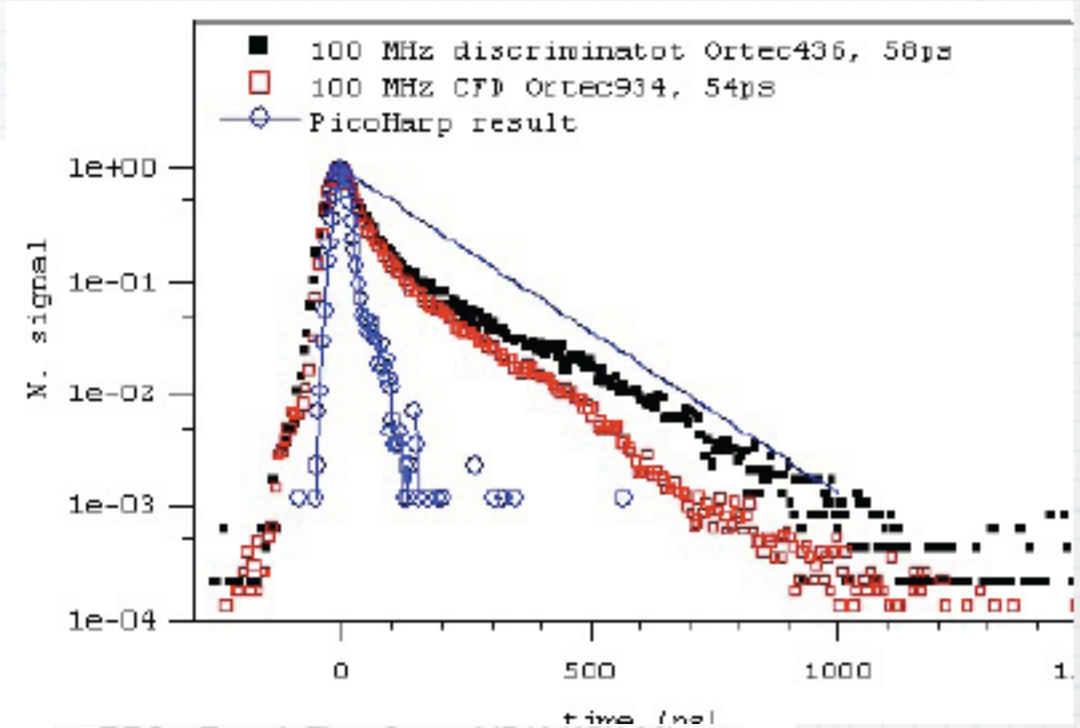


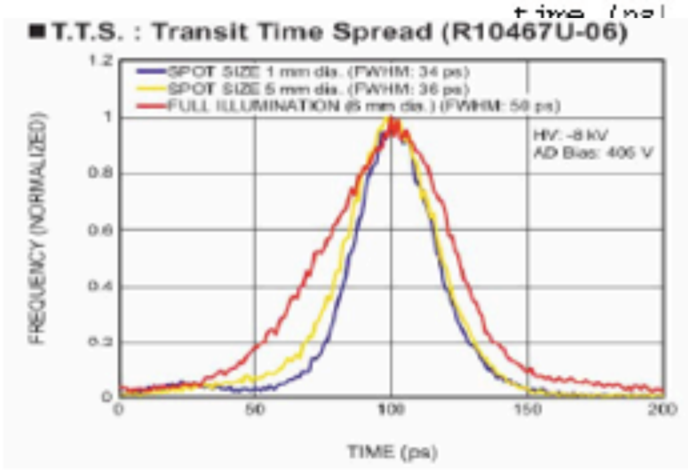


11 psec single photon response is not common. Below studies comparing LE, CFD, PicoHarp









$$\sigma_{TOF} = \sqrt{\sigma^2_{HPD} + \sigma^2_{radiator} + \sigma^2_{electronics}}$$

$$\sigma_{HPD} = \frac{\sigma_{TTS}}{\sqrt{N_{pe^-}}} = \frac{11\ ps}{\sqrt{N_{pe^-}}}$$

Reconstruction of ZDC Pre-Processor Data and its timing Calibration

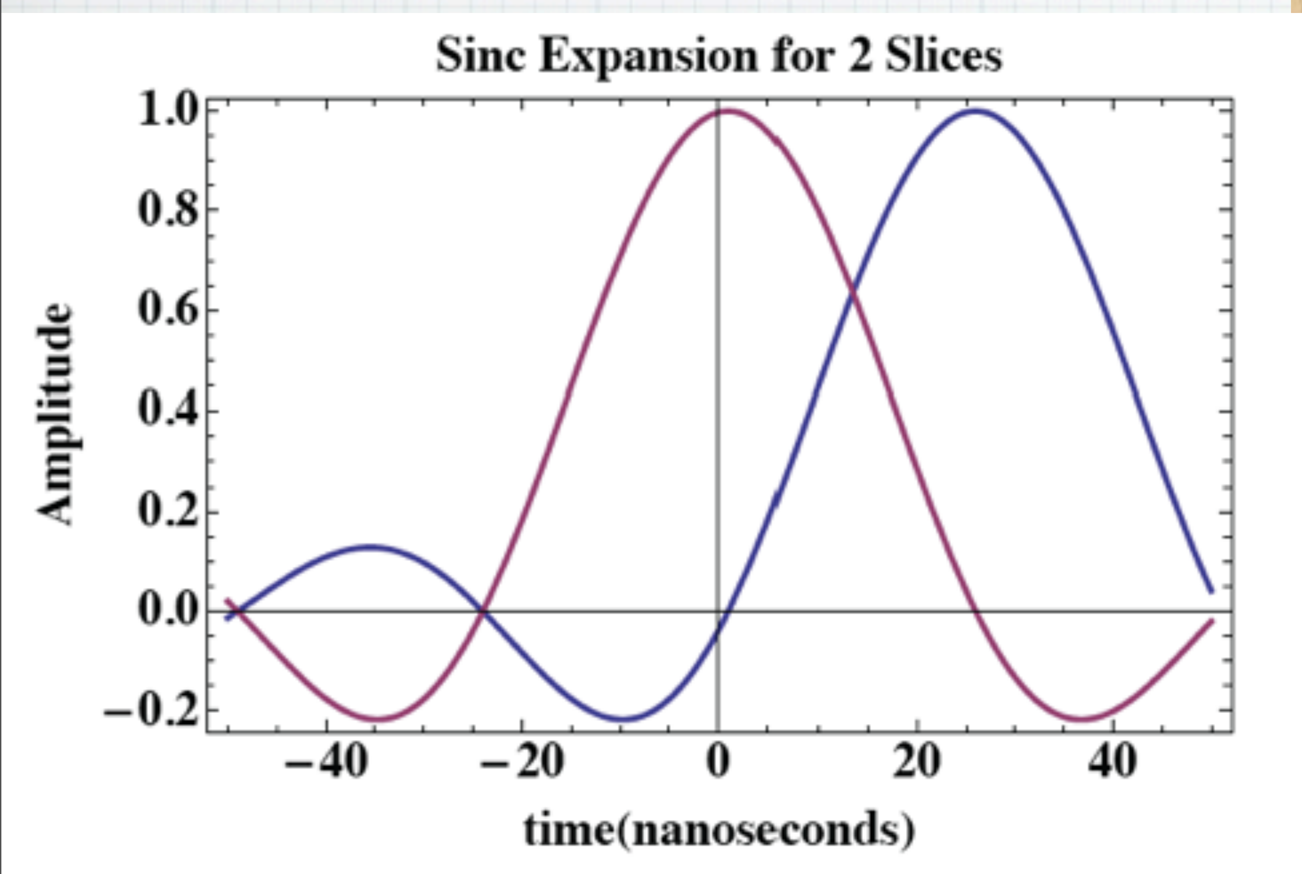
Soumya Mohapatra, Andrei Poblaguev and Sebastian White

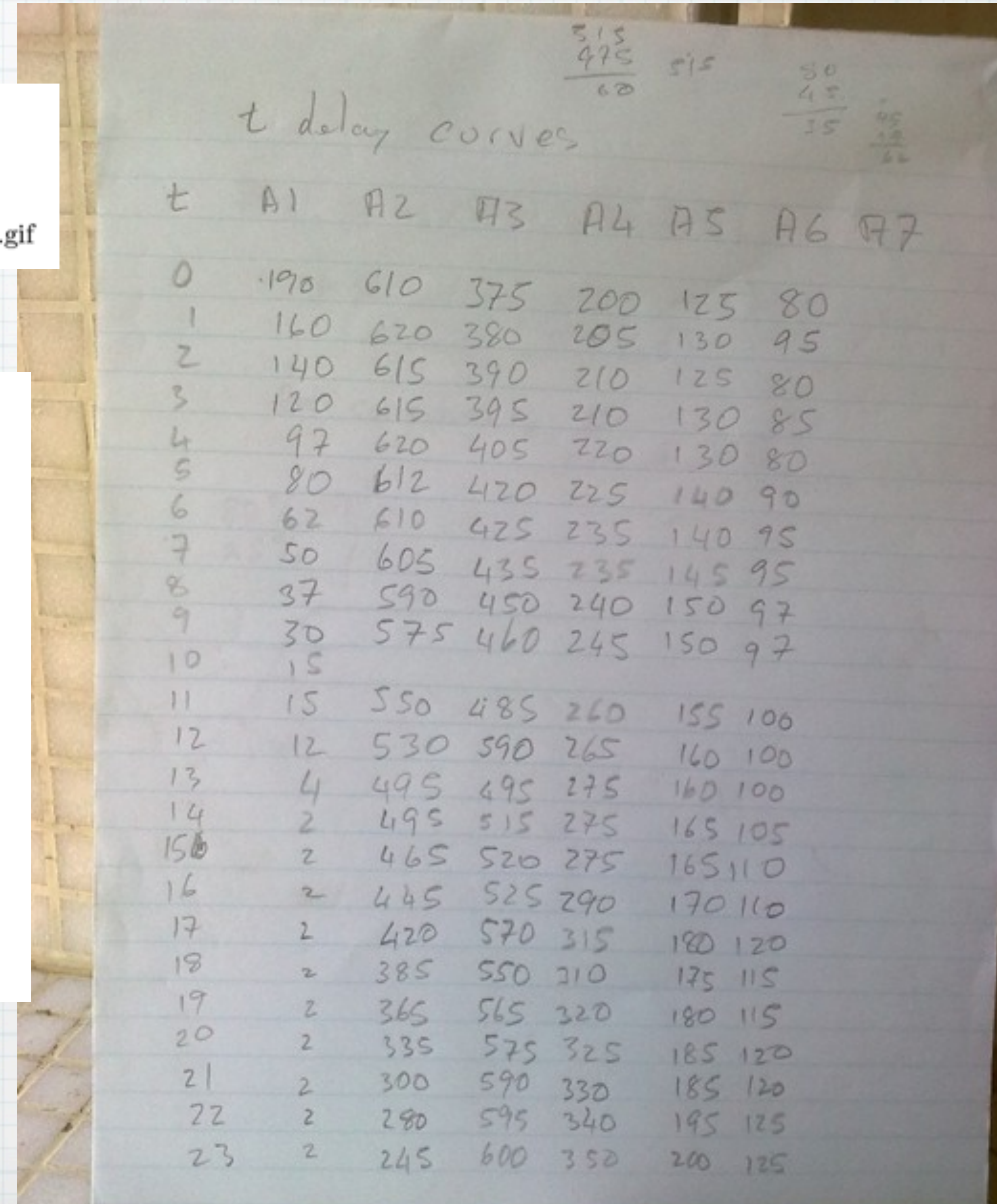
Aug.8,2010

ATLAS data set used to develop ZDC reconstruction and do L1calo calibration (in Mathematica 7.0)

$$shannon[t] = \sum_{i=1}^{nslice} slice[i] \times Sinc[\pi \times (t - time(i))/25] \qquad (6)$$

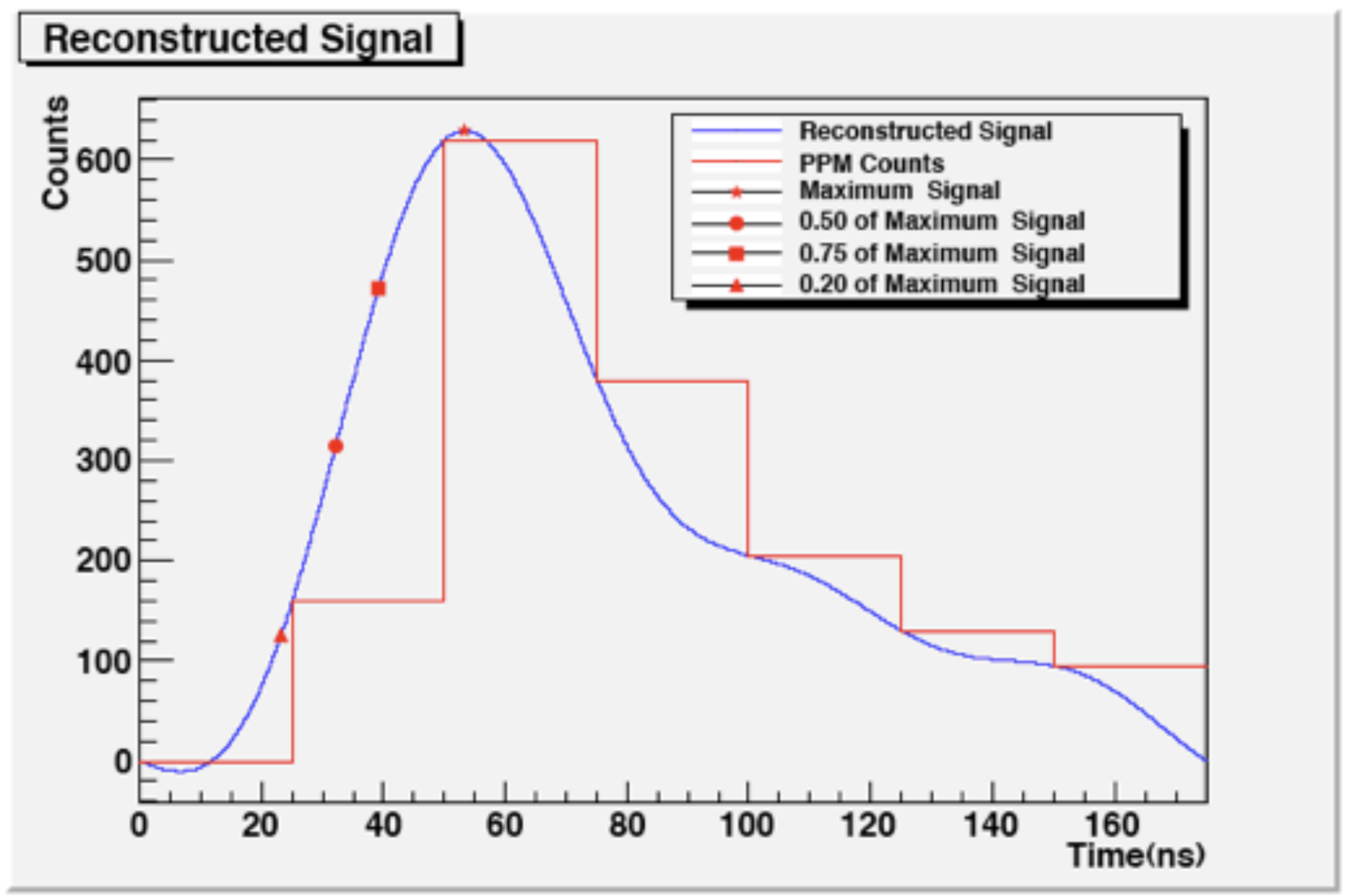
An animated gif can be found at:
http://www.phenix.bnl.gov/phenix/WWW/publish/swhite/ShannonFilm.gif

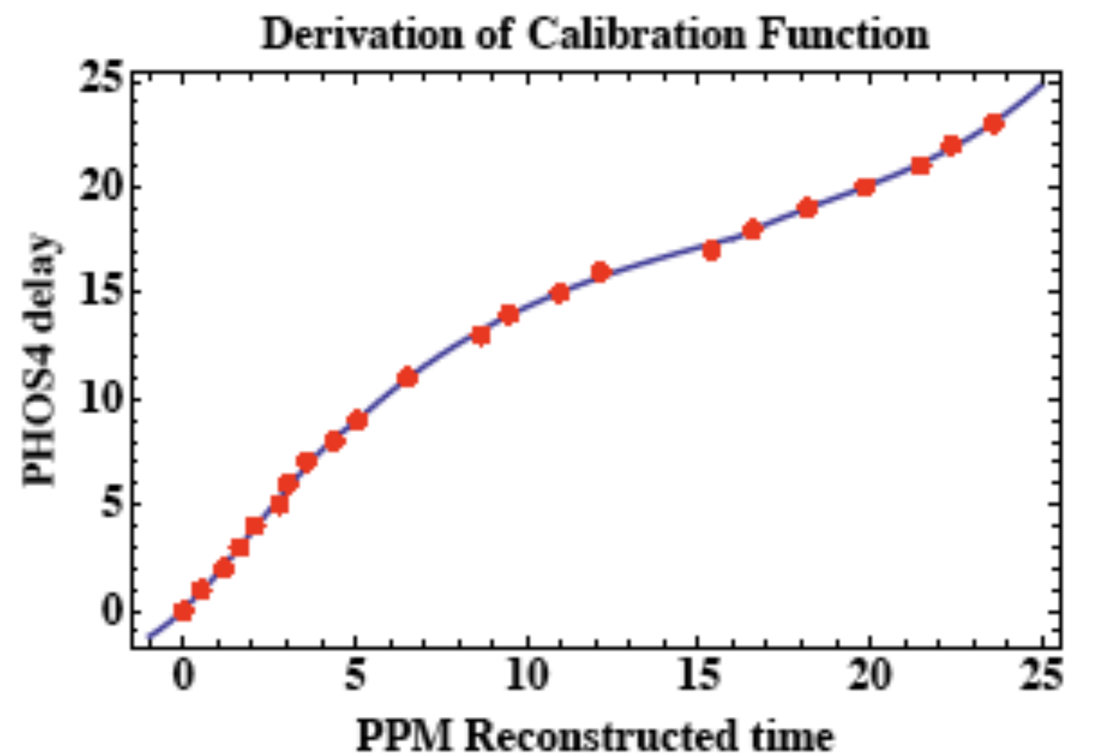




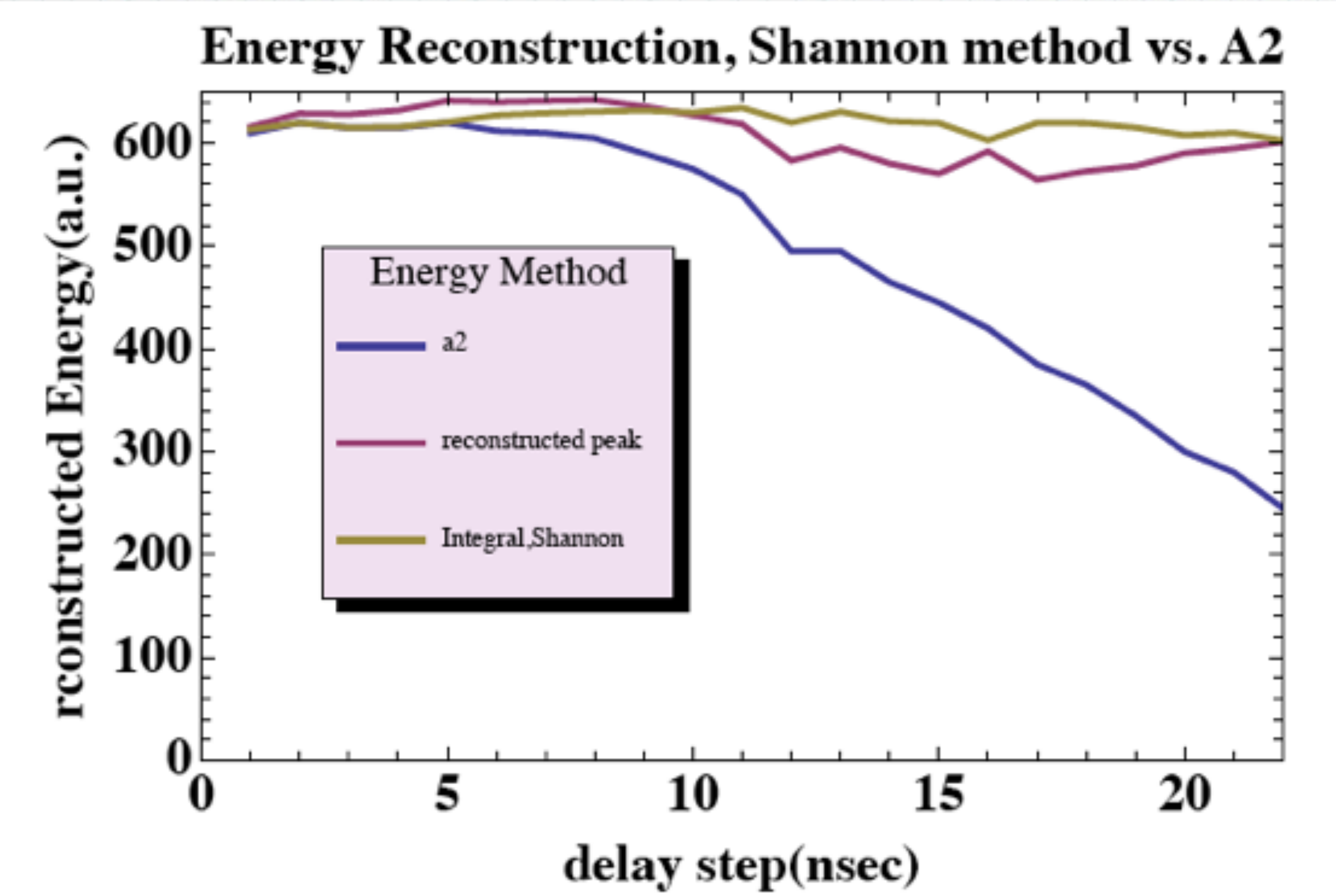
t delay curves

t	A1	A2	A3	A4	A5	A6	A7
0	190	610	375	200	125	80	
1	160	620	380	205	130	95	
2	140	615	390	210	125	80	
3	120	615	395	210	130	85	
4	97	620	405	220	130	80	
5	80	612	420	225	140	90	
6	62	610	425	235	140	95	
7	50	605	435	235	145	95	
8	37	590	450	240	150	97	
9	30	575	460	245	150	97	
10	15						
11	15	550	485	260	155	100	
12	12	530	590	265	160	100	
13	4	495	495	275	160	100	
14	2	495	515	275	165	105	
15	2	465	520	275	165	110	
16	2	445	525	290	170	110	
17	2	420	570	315	180	120	
18	2	385	550	310	175	115	
19	2	365	565	320	180	115	
20	2	335	575	325	185	120	
21	2	300	590	330	185	120	
22	2	280	595	340	195	125	
23	2	245	600	350	200	125	

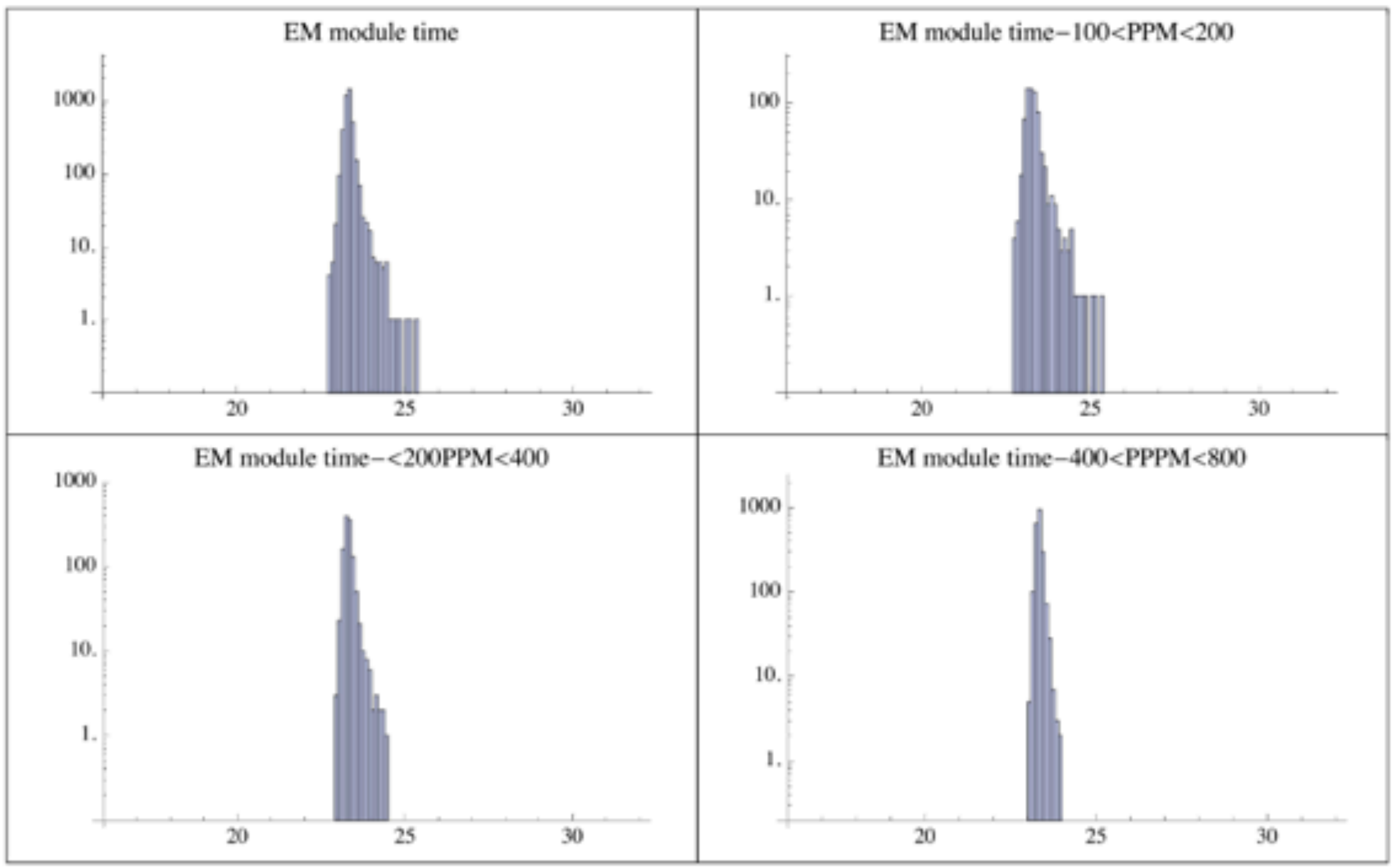




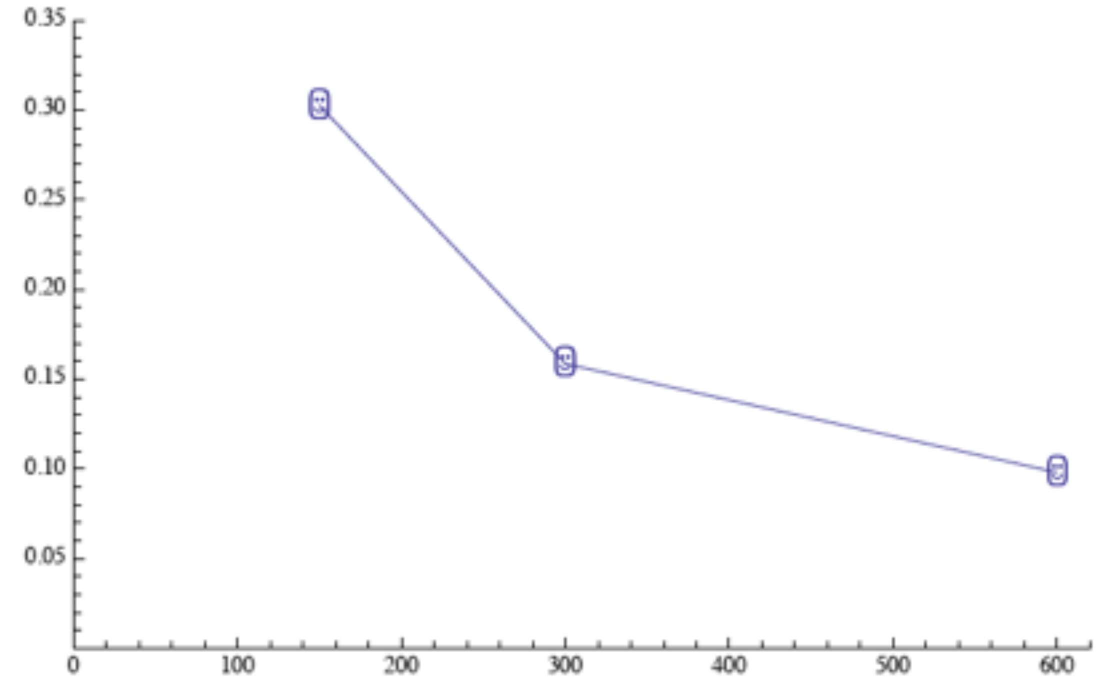
(d) Piecewise fit to the full range.



```
{7.0 for Mac OS X x86 (64-bit) (February 19, 2009), /Users/white, 15 786 240}

Timing[ATLASdata = Import["/afs/cern.ch/user/s/spagan/public/run160953.root"]] [[1]]

1.15994

nevents = Dimensions[ATLASdata][[1]]
{EMASignal, EMATime, EMAErrorFlag, HD0ASignal, HD0ATime, HD0AErrorFlag, HD1ASignal,
    HD1ATime, HD1AErrorFlag, HD2ASignal, HD2ATime, HD2AErrorFlag, EMCSignal,
    EMCTime, EMCErrorFlag, HD0CSignal, HD0CTime, HD0CErrorFlag, HD1CSignal, HD1CTime,
    HD1CErrorFlag, HD2CSignal, HD2CTime, HD2CErrorFlag} = Transpose[ATLASdata] ;

12 848

TEMA0 = Pick[EMATime, Thread[100 < EMASignal < 800]];
TEMA1 = Pick[EMATime, Thread[100 < EMASignal < 200]];
```



rms (nsec) of 3” H0 PMT vs. energy deposit



Application of commercial software to ATLAS data analysis

Dear Sebastian,

I have not yet contacted Tony as I also have been swamped with other tasks.

One potential issue of concern is that CERN ROOT is available under the Lesser General Public License (http://root.cern.ch/root/License.html). As I understand it (and I'll have this clarified by our legal department), we can not make use of any ROOT source code without exposing the Mathematica source code (which obviously is not an option). If true, this hurdle may be bigger than any technical problems we may face.

Ken

(I then held discussions with Brun and Rademaker at CERN, who were enthusiastic.)

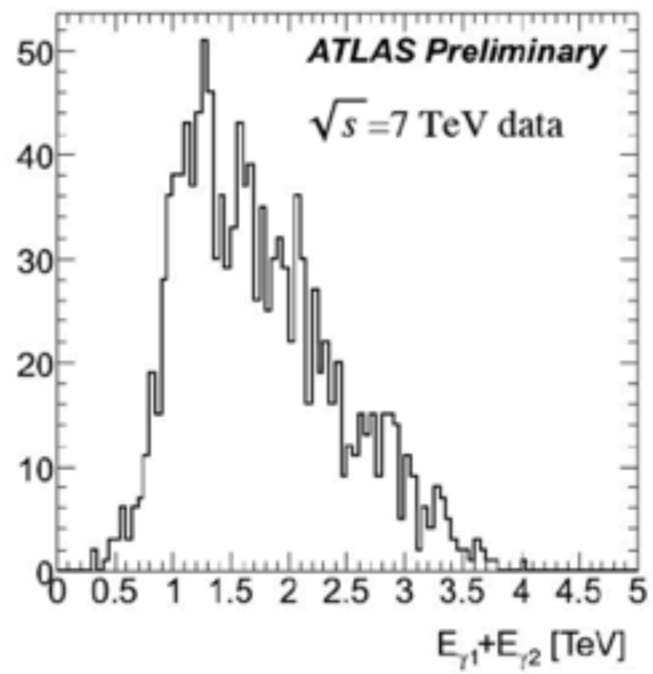
Hello Sebastian,

I am sorry about the silence these days as I am still waiting on words from our legal department. I feel that it is best that I respond once I have any news on this front. In the mean time, I am taking the assumption that all will be legal, and have actually started to implement some items.

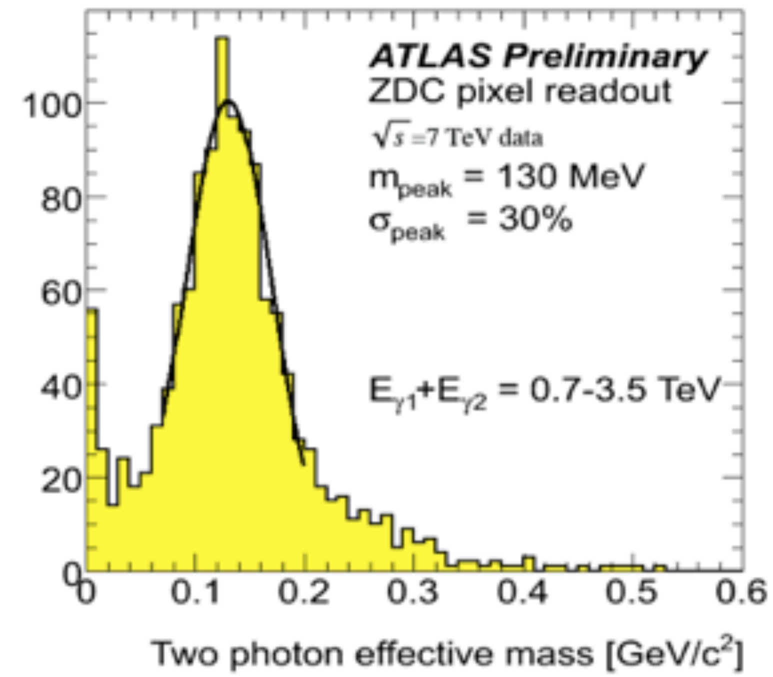
We are also very, very close to release here, and all our efforts are dedicated to it now. However, you can be assured that once Mathematica 8 is released, this will be a the first Mathematica 9 project I undertake.

Ken

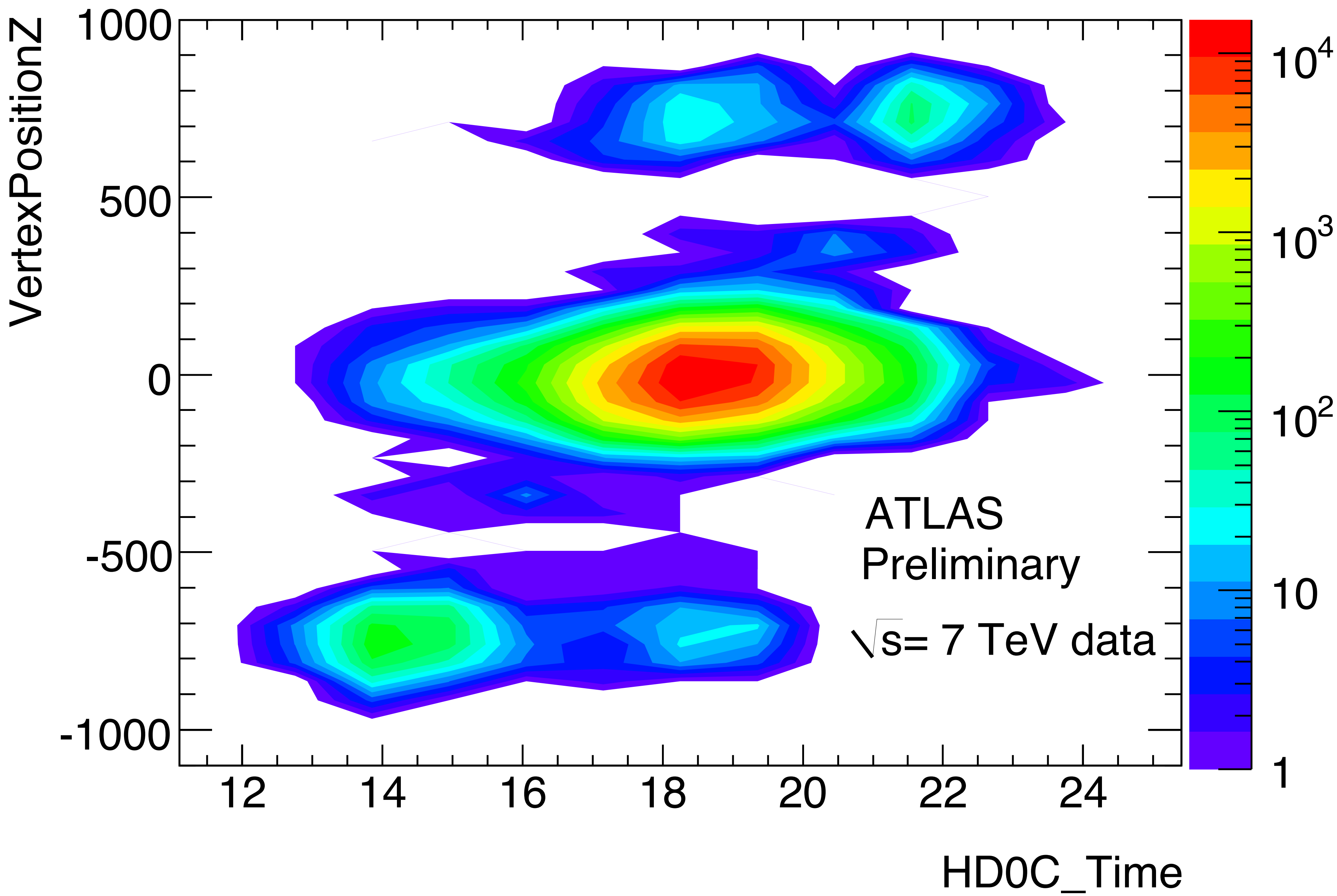
2 photon



Energy distribution of 2 photon candidates in the ZDC, selected using the longitudinal shower profile. The ZDC energy scale was established using the endpoint measured in 7 TeV collision data. Since the shower energy is concurrently measured in the "pixel" coordinate readout channels this allows energy calibration to be established for these channels also.



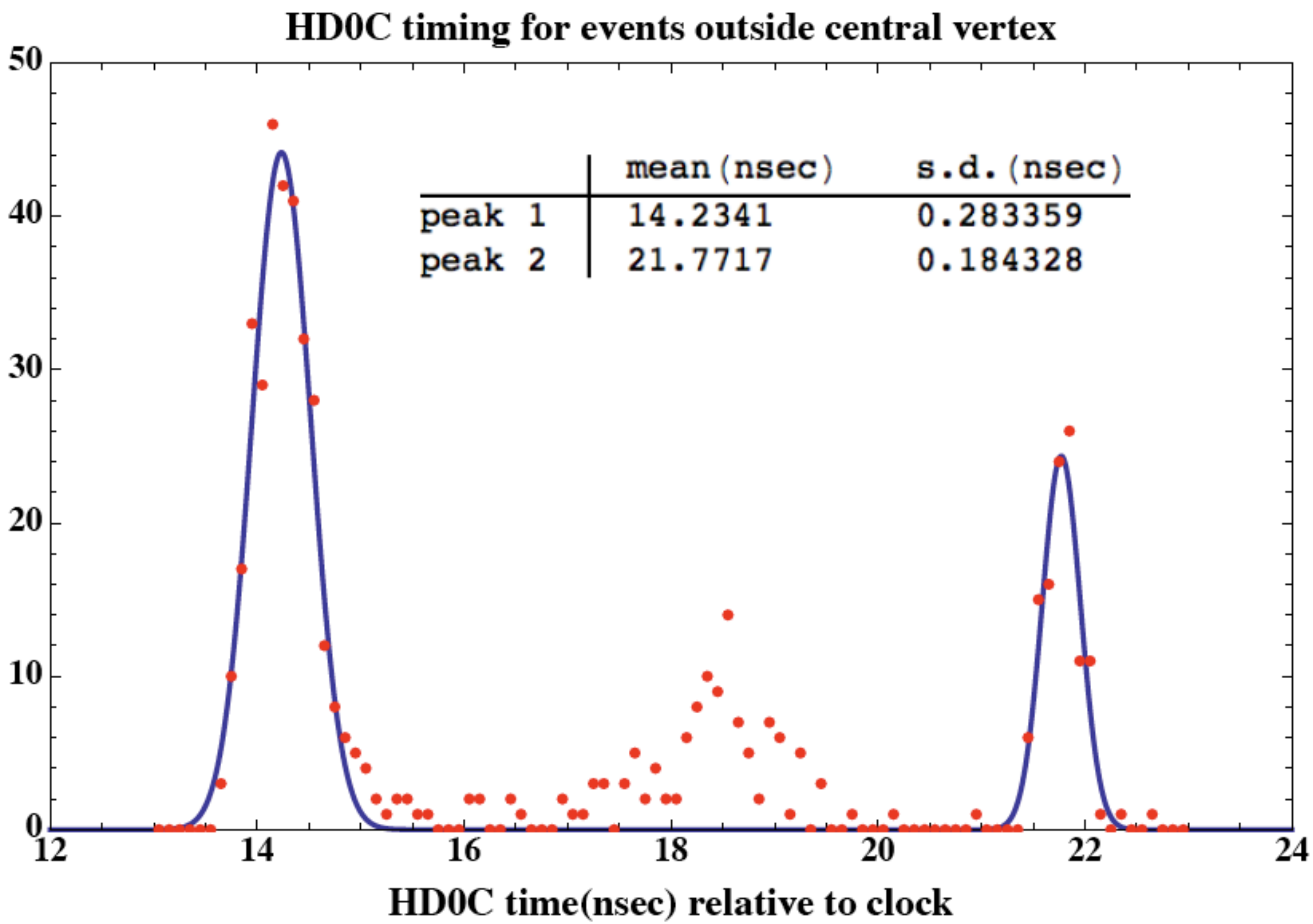
For 7 TeV collision data taken prior to LHCf removal the first ZDC module is the so-called "Hadronic x,y" which has identical energy resolution to all of the other ZDC modules. The coordinate resolution, however, is inferior to that of the high resolution EM, installed 7/20/10. Nevertheless, the reconstructed mass resolution is found to be 30% at m=130 MeV. As is foun in ongoing simulation of pi0 reconstruction within the full ATLAS framework (see ZDC simulatic TWIKI), the pi0 width is completely dominated by the energy resolution. Therefore, the current state of ATLAS ZDC photon energy resolution can be inferred from this plot.



The Z vertex distribution from inner tracker vs. the time of arrival of showers in ZDC-C relative to the ATLAS clock calculated from waveform reconstruction using Shannon interpolation of 40 MegaSample/sec ATLAS data (readout via the ATLAS L1calo Pre-processor modules). Typical time resolution is ~200 psec per photomultiplier (see ATL-COM-LUM-2010-022). The two areas outside the main high intensity area are due to satellite bunches. Note that this plot also provides a more precise calibration of the ZDC timing (here shown using the ZDC timing algorithm not corrected for the digitizer non-linearity discussed in ATL-COM-LUM-2010-027). With the non-linearity correction the upper and lower satellite separations are equalized.

Support material for blessing:

"anyone who abandons what is for what should be pursues his downfall rather than his preservation"
Niccolo Machiavelli



Some links

- http://library.wolfram.com/infocenter/Articles/7716/
- this bullet will be replaced by links on CERN ROOT pages and on Wolfram.com for release of the Mathematica_ROOT package. see also attached examples and mac user guide for dummies.